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NEW INSULATION CONSTRUCTIONS FOR AEROSPACE WIRING APPLICATIONS

Volume II: 270 VDC Arc Tracking Testing with Power Controllers

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This program evaluated the ability of wire insulations to inhibit arc propagation during short circuit conditions in 270 volt dc power distribution systems. Evaluations were performed using Dry Arc Propagation tests on three inorganic insulations in unprotected harnesses and on four candidate and two baseline insulation constructions protected by power controllers or solid state circuit breakers. Six different power controllers were tested. Evaluations showed the three unprotected inorganic insulations were not able to inhibit arc propagation in a 270 volt dc power distribution system. The three solid state power controllers demonstrated good to excellent performance in inhibiting arc propagation in 270 volt dc power distribution systems, and two of the three electromechanical controllers demonstrated moderate abilities. The third electromechanical controller was not able to inhibit arc propagation. The insulation constructions played no part in inhibiting arc propagation.

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ABSTRACT

The objective of Amendment #2 testing was to further evaluate the ability of insulations to inhibit arc propagation during short circuit conditions in 270 volt dc power distribution systems. Evaluations were performed using Dry Arc Propagation tests on three inorganic insulations in unprotected harnesses and on four candidate and two baseline insulation constructions protected by power controllers. Six different power controllers were tested. Evaluations showed that the three unprotected inorganic insulations were not able to inhibit arc propagation in a 270 volt dc power distribution system. The three solid state power controllers demonstrated good to excellent performance in inhibiting arc propagation in 270 volt dc power distribution systems, and two of the three electromechanical controllers demonstrated moderate abilities. The third electromechanical controller was not able to inhibit arc propagation. The insulation constructions played no part in inhibiting arc propagation.

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1.0 INTRODUCTION

The objective of this test program was to evaluate the performance of several different wire insulations under short circuit conditions in a 270 volt dc power system. The first segment of the test program evaluated inorganic insulations in unprotected circuits. The three inorganic insulations were supplied by Champlain Cable, Thermatics, and Independent Cable. The test evaluation consisted of a Dry Arc Resistance and Fault Propagation Test according to a draft presented to ASTM D09.16, dated October 18,1989. The second segment of the test program evaluated Dry Arc Resistance and Fault Propagation of four candidate insulation constructions and two baseline constructions. This second test was conducted with six different sets of power controllers placed in series with the test harness for protection. The candidate insulation constructions tested were provided by Filotex, National Electrical Manufactures Association, Tensolite and Thermatics. The two baseline constructions were M81381 (fluoropolymer/ polyimide) and M22759 (crosslinked ethylene tetrafluoroethylene). The power controllers used for circuit protection were supplied by Eaton, Hartman, ILC Data Device Corporation, Kilovac, Teledyne Solid State and Texas Instruments. This second test evaluated the resistance to arc propagation of the wire insulation when used in conjunction with power controllers in a 270 volt dc system.

This test was conducted by the Electrical Systems Laboratory during the period 20 August to 28 November 1990.

2.0 270 VOLT DC DRY ARC PROPAGATION TEST WITH INORGANIC INSULATION

2.1 Scope:

This test was used to measure the ability of inorganic insulations to inhibit or eliminate arc propagation during short circuits of 270 volt dc power in aircraft power distribution harnesses.

2.2 Reference Procedure:

The 270 volt dc Dry Arc Propagation Test with inorganic insulations was performed according to a draft submitted to the American Society for Testing and Materials Subcommittee D09.16, dated October 18, 1989 (see Appendix A). The test method initiates an arc by applying a thin layer of copper dust onto the flush cut conductor ends of the harness. No circuit protection was included.

2.3 Specimens:

The inorganic insulated wire for the test program was supplied by Champlain Cable, Independent Cable and Thermatics. Three harnesses were fabricated for each insulation that was evaluated, for a total of nine harnesses. The three insulations that were evaluated are described in Table 1.

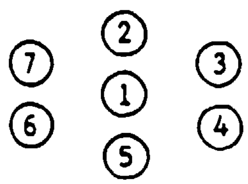
TABLE 1 - CONDUCTOR AND INORGANIC INSULATION DESCRIPTION

(1) Thermatics - 7/0.0242", 14 gauge, bare copper coated with silicone for water proofing, insulated with a wrap of mica tape covered with a braid of fiberglass.

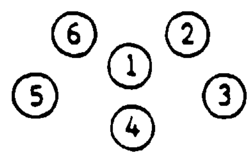
(2) Champlain Cable - 19/32, 20 gauge, 27% nickel plated alloy (PD135), true concentric stranding, with insulation of cross wrapped, glass reinforced mica covered by a braid of fiberglass impregnated with silicone.

(3) Independent Cable - 19/25, 12 gauge, nickel plated copper, true concentric stranding, with two mica tapes and a Teflon coated fiberglass tape.

Thermatics and Champlain
Wire Configuration



Independent
Wire Configuration



Cable 1 - Wires 1,2,3
Cable 2 - Wires 4,5,6

FIGURE 1 - WIRE ARRANGEMENTS WITHIN HARNESS

The Champlain and Thermatics test harnesses consisted of seven parallel wires with a finished harness length of 48±1 inches. The Independent test harnesses consisted of two parallel laid triplet cables, for a total of six wires in the harness. Approximately eight inches of the outer jacket was removed from both ends of the twisted triplet cable to permit connections on one end and achieve proximity of all six wires on the opposite end. The finished harness length was 48±1 inches. A black Nomex lacing cord (MIL-T-43435B, Type IV, Finish D) was used to secure all harnesses in the appropriate wire arrangement shown in Figure 1.

All harnesses were constructed by cutting seven (or six) wires to a length of approximately 54 inches. The wires were placed in the appropriate locations of two 19 socket Burndy connectors (P/N G0A16-19SNE), which were held firmly in two vises 51 inches apart. The wires also passed through a third connector with grommet removed which was allowed to slide freely along the length of the harness between the two fixed connectors. This connector was used to assure proper parallel orientation of the wires when securing the string ties to the harness. The first Nomex string tie was securely placed one half inch from one of the connectors by tying a square knot on top of a clove hitch. Subsequent string ties were placed at one inch intervals for the first seven inches from the shorting end of the harness and then every two inches for an additional 36 inches. The remaining section of the harness was left untied. The shorting end of the harness was cut at the connector face using a pair of Klein pliers (P/N 63050). The opposite end was cut to achieve a final harness length of 49 inches. This end of the harness had a one quarter inch of the insulation removed and was terminated with spade terminals. Each wire was identified by numbers 1 through 7 (or 6).

2.4 Test Equipment:

The power source used was a 270 volt dc, 30,000 Watt, Westinghouse Electric Corporation Generator (modified AV-8B Generator) (P/N ED408067-001) with corresponding Generator Control Unit (P/N ED408068-001). The Generator Control Unit was configured to current limit the output of the generator to approximately 289 amps. If the generator experienced a short circuit greater than five seconds, the Generator Control Unit removed the Exciter Field Current and opened the Main Line Contactor. The Main Line Contactor was a Hartman (Model# A-75JD) 270 volt dc Power Contactor (S/N CH-83865) which was used to initiate the dry arc propagation test. A Jack and Heintz Power Contactor (Model# 50086-001) was placed in series with the circuit as a fail safe in case of any emergency (it remained closed until required). Two lights were attached to the backboard of the harness support fixture to indicate whether the Generator was "on line" and when power was applied to the harness. Electrical schematics and mechanical drawings of the test setup are presented in Appendix B.

The test setup was designed to monitor the currents in each of the powered conductors within the harness. Wires #2, #4, and #6 had 200 amp, 50 millivolt Weston shunts placed in series with the corresponding conductors. Wires #1, #3, #5, and #7 were connected together at a terminal block and connected to the return of the generator through the generator return current shunt. The generator output current and generator return current were monitored using Weston 450 amp, 50 millivolt shunts. These differential signals were converted to single ended signals by the use of Preston Instrumentation Amplifiers. The single ended signals were then recorded on an eight channel Soltec Signal Memory Recorder (MD 117327) and stored on five and a quarter inch disks. The generator output voltage was also recorded on the Soltec through a 10:1 voltage divider located at the terminals of the generator. The Soltec was configured for a sample rate of 0.1 milliseconds for 65,536 samples per channel with a 12.5% pre-trigger delay, for a total test recording time of 5.7 seconds. An instrumentation list is provided in Table 2.

The harness mounting fixture consisted of a 60 x 36 x 0.5 inch plywood backboard painted with a high temperature, gray epoxy resin based primer to make the board flame resistant. A 36 x 24 x 0.5 inch Bakelite board was placed beneath the test setup to collect any molten or burning debris. Two 7 x 4 inch Bakelite collars with 0.3125 inch diameter holes were made to hold the harness in place six inches from the backboard. The top Bakelite collar was fixed in position at fifteen inches beneath the seven terminal Jones strip from where power to the harness was applied according to Table 3. The lower Bakelite collar was attached to a 0.375 inch threaded drill rod to make its position adjustable. The lower collar was vertically positioned six inches from the actual shorting end of each harness.

TABLE 2 - INSTRUMENTATION LIST

SOLTEC CHANNEL	PARAMETER MEASURED	TRANSDUCER	AMPLIFIER GAIN	AMPLIFIER BANDWIDTH
1	Generator Output Voltage	10:1 Voltage Divider	----	---------
2	Generator Output Current	Weston Shunt 450 Amp = 50 mV (MD 140729)	Preston Amplifier 100	10,000 Hz (MD 071662)
3	Generator Return Current	Weston Shunt 450 Amp = 50 mV (MD 140730)	Preston Amplifier 100	10,000 Hz (MD 071661)
4	Wire #2 Current	Weston Shunt 200 Amp = 50 mV (MD 142486)	Preston Amplifier 50	10,000 Hz (MD 071648)
5	Wire #4 Current	Weston Shunt 200 Amp = 50 mV (MD 109154)	Preston Amplifier 50	10,000 Hz (MD 071653)
6	Wire #6 Current	Weston Shunt 200 Amp = 50 mV (MD 109152)	Preston Amplifier 50	10,000 Hz (MD 071638)

TABLE 3 - HARNESS POWER ASSIGNMENT

WIRE NUMBER	POWER SOURCE
1	- 270 Vdc
2	+ 270 Vdc
3	- 270 Vdc
4	+ 270 Vdc
5	- 270 Vdc
6	+ 270 Vdc
7 (if available)	- 270 Vdc

A copper dust applicator was fabricated to apply a thin even layer of copper dust to the shorting face of the harness. The 2 x 6 x 0.25 inch plate of low carbon, precision ground steel had a 0.3125 inch diameter hole for the Thermatics (14 gauge) and Champlain (20 gauge) harnesses and a 0.5 inch diameter hole for the Independent (12 gauge) harnesses both drilled to a depth of 0.015±0.001 inches. The base of the hole was machined flat to within 0.001 inches.

The Dry Arc Propagation Tests were recorded on one inch video tape (30 frames per second) and high speed, 16 mm film (400 frames per second) to provide a record of any arcing or flaming of the test harnesses.

Photographs and schematics of the test set up are presented in Appendix B.

The tests were conducted at MCAIR's Electrical System's Generator Testing Laboratory with exhaust fans on. All personnel were in the control room during the arc propagation test to avoid contact with flying molten debris and toxic gases.

2.5 Test Procedure:

The harness test specimen was placed in the setup by securing the appropriate spade terminals to the seven terminal Jones strip corresponding to the power assignments of Table 3. The harness was positioned in the Bakelite collars with the lower collar adjusted to 7±0.25 inches from the end of the test harness. After positioning the harness within the setup, one inch of the harness was cut off using a pair of Klein pliers (P/N 63050) that resulted in a quarter of an inch of the harness extending beyond the last string tie. The harness end was trimmed using sharp scissors to assure that all wires were cut flush with one another. The appropriate diameter hole of the copper dust applicator was filled with purified grade metal copper (electrolytic dust). A single edged razor blade was used to smooth the dust flush with the face of the applicator. The shorting end of the harness was dipped into the copper dust with the applicator perpendicular to the harness to ensure an even application. After application, the face of the harness was checked with a mirror to ensure that all conductors were evenly coated with copper dust. If not, the copper dust applicator was refilled and reapplied until [illegible] entire shorting face of the harness was covered. Care was [illegible] to ensure that copper dust was applied only to the shorting face of the harness and not around the edges of the insulation.

The test commenced by bringing the generator speed up to approximately 4050 revolutions per minute. The video equipment was started and the instrumentation was armed to trigger from any current in the generator output or return. The Hartman contactor was closed to initiate the dry arc propagation test by applying power to the harness. Power was applied to the specimen for a minimum of five seconds before the generator was brought off line automatically using the generator control unit or manually. If the short circuit continued for more than five seconds, the generator control unit automatically shut off the generator by removing the exciter field current and opening the main line contactor. If arcing stopped prior to the five seconds, the generator was brought off line manually. The data acquired was stored on 5¼ inch disks. A minimum of five minutes elapsed after completion of the test before personnel were permitted to enter the test area to allow the exhaust fans to eliminate the toxic gases generated.

Three harnesses were tested for each inorganic insulation construction, for a total of nine tests.

2.6 Test Results:

The specimens were inspected for physical phenomenon such as carbonization of the insulation, length of charring or black carbon residue on the harness, exposed or recessed conductor length, and the amount of harness consumed by the test. The inorganic insulation test data is presented in Appendix C. Appendix C also includes short circuit current durations detected by the shunts, the peak currents observed at the arc initiation, and whether power was removed manually or by the generator control unit. The video provided information about the smoke, secondary fire, and presence of arcing. Photographs were taken of the test end of the harness after removal from the test setup and are presented in Appendix D.

2.7 Discussion of Test Results:

None of the three tested inorganic insulations inhibited dry arc propagation in a 270 volt dc power system. In all but one Thermatics test harness, the generator control unit reached its five second overcurrent trip limit and brought the generator off line by opening the Hartman main line contactor. In the case where the Thermatics harness extinguished the arc before the five second limit, the arc current duration was measured to be 4.60 seconds, which is not significantly less than the 5.0 second overcurrent trip limit. The Independent insulation was judged by visual appearance to incur the least amount of physical damage. A factor in this assessment is that Independent was the largest gauge size tested and a considerable amount of energy was used to consume the larger mass of copper.

In general, the inorganic insulations sustained the arc longer than the ten new candidate and two baseline insulation constructions tested in Amendment #1. The average current duration through harnesses in Amendment #1 tests was approximately two seconds, and the generator tripped out at the five second limit in only one harness, where all but one harness in Amendment #2 sustained the arc for the full five seconds to generator time out. Although the sustained current duration was less for Amendment #1, the test harnesses revealed more damage throughout the length of the harness, rather than limited to the test end as with the inorganic harnesses.

It is proposed that the differences in sustained current duration and the amount of damage between Amendments #1 and #2 are due to the differences in gauge size. All of the inorganic specimens were of a larger gauge and therefore required more energy just to consume the copper conductor at the harness test end, without propagating further into the harness. The larger gauges also did not fuse as the smaller gauges in Amendment #1 did. This allowed the arc to be sustained for a greater amount of time in the inorganic harnesses.

3.0 270 VOLT DC DRY ARC PROPAGATION TEST WITH POWER CONTROLLERS

3.1 Scope:

This test was used to measure the ability of an insulation construction in conjunction with a set of power controllers, as a system, to inhibit or eliminate dry arc propagation during short circuits of 270 volt dc power in aircraft power distribution harnesses.

3.2 Reference Procedure:

The 270 volt dc Dry Arc Propagation Test, conducted on four candidate and two baseline insulations protected by power controllers, was performed according to a draft submitted to the American Society for Testing and Materials subcommittee D09.16, dated October 18, 1989 (see Appendix A). This test used power controllers instead of circuit breakers for circuit protection. The test method initiates an arc by placing a thin layer of copper dust onto the flush cut conductor ends of the harness. The power controllers were activated and the main line contactor was energized to supply power to the harness.

Functional tests were performed on the power controllers initially and after each dry arc propagation test. The power controllers were tested to either MIL-P-81653C, MIL-R-28750B, or MIL-R-6106J. Three functional tests were performed on the power controllers to check for proper operation and whether any degradation of the controller had occurred. The tests performed were Turn-on and Turn-off Time, Voltage Drop, and Trip Time for a 300% overload.

3.3 Specimens:

The four candidate insulation constructions evaluated in this segment of the test program were supplied by Filotex, National Electrical Manufactures Association (NEMA), Tensolite and Thermatics. In addition to the four candidates, two baseline constructions were evaluated, M81381 and M22759. Six harnesses were fabricated for each insulation construction, for a total of thirty six harnesses. Four of the six harnesses were constructed from 22 gauge, 5.8 mil wall, hook-up wire and two were 12 gauge, 8.6 mil wall, airframe wire. Conductor size was chosen to match the current capacity of the wire to the power rating of the controllers. The six insulation constructions that were evaluated are listed in Table 4.

TABLE 4 - INSULATION CONSTRUCTION DESCRIPTIONS

(1) M81381 (#201 - 12 gauge, #202 - 22 gauge) - Kapton Tape (50% min. overlap) / cross-wrapped Kapton Tape (50% overlap) / 0.5 mil modified polyimide topcoat
(2) M22759 (#206 - 12 gauge, #207 - 22 gauge) - Extruded Crosslinked Modified ETFE
(3) Filotex (#236 - 12 gauge, #237 - 22 gauge) - PTFE Tape / 616 Kapton Tape / PTFE Dispersion
(4) Tensolite (#241 - 12 gauge, #242 - 22 gauge) - 2919 Polyimide - Fluorocarbon Tape / PTFE Tape
(5) Thermatics (#246 - 12 gauge, #247 - 22 gauge) - Modified PTFE Tape / 2919 Kapton Tape / Modified PTFE Tape
(6) NEMA #3 (#256 - 12 gauge, #257 - 22 gauge) - 616 Kapton Tape / Extruded XL ETFE

Each type of wire insulation was tested once with each set of power controllers. A set of three power controllers was submitted for the test program by each of the following manufacturers: Eaton, Hartman, ILC Data Device Corporation, Kilovac, Teledyne Solid State and Texas Instruments. Manufactures were given a goal of 40 millisecond maximum trip time for submitted power controllers. A description of each manufacturer's power controller is listed below:

Teledyne Solid State (5 Amp) - Teledyne Solid State provided three solid state relays, part number VD46KKW. The devices are rated at 5 amps continuous current with unlimited rupture current. They operate in a range of 10 to 300 volts dc, and are capable of handling surge voltages up to 470 volts dc and transients of ±600 volts peak. The relays are configured as single pole, single throw, normally open devices. The specified turn-on time includes a 0.9 millisecond delay time and 0.1 millisecond rise time. The specified turn-off time includes a 0.7 millisecond delay and 0.3 millisecond fall time. The device requires a 5 volt dc bias voltage with a 45 milliamp current draw and a 5 volt dc control voltage with a current draw of 0.1 milliamps. The power controllers provided both trip and flow status signal output. The trip circuits function according to an I^2T trip curve. Short circuit protection was also designed into the devices, and they will trip immediately when an overload of 1800% or greater was sensed by the devices.

Texas Instruments (10 Amp) - Texas Instruments provided three prototype remote power controllers, part number EX 3407-100-10. These solid state devices are rated at 10 amps continuous current, and provide a current limiting function between 30 and 50 amps. They operate at 270 volts dc nominal, with a range of 250 volts dc to 280 volts dc per MIL-STD-704D requirements. The power controllers are configured as single pole, single throw, normally open devices. The turn-on time was specified to be 2.0 milliseconds maximum, and the specified turn-off time was 2.0 milliseconds maximum. They require a 28 volt dc bias voltage and a 5 volt dc control voltage. They provide both trip and flow status signal output. They utilize a time-current trip curve with a minimum ultimate trip at 115% of rated current and a maximum ultimate trip at 138% of rated current. At 200% rated current, they are specified to trip within 5 to 13 seconds; at 300% rated current, they are specified to trip within 2 to 4.8 seconds; and at 400% rated current, they should trip within 1 to 2.6 seconds. A thermal memory is used to shorten trip times.

ILC Data Device Corporation (15 Amp) - ILC Data Device Corporation provided three solid state power controllers, part number 19645 SSP-21116-015 9046. The solid state power controllers are rated at 15 amps continuous current with an unlimited rupture current. They are designed to operate at 270 volts dc nominal, with a range of 100 volts dc minimum to a maximum of 480 volts dc. They utilize power MOSFET (Metal Oxide Semiconductor Field Effect Transistor) switches in a single pole, single throw, normally open configuration. The specified turn-on time includes a 150 micro-second delay with a 200 micro-second rise time. The specified turn-off time includes a 130 micro-second delay and a 200 micro-second fall time. The power controllers require a 5 volt dc bias supply voltage with a maximum current draw of 60 milliamps with a 5 volt dc control voltage. The control input is TTL/CMOS compatible. They provide both trip and flow status signal outputs. Two separate sensing circuits are incorporated into the device. An I^2T comparator controls tripping at up to 800% rated load current and the short circuit sensing circuit controls tripping, in less than 25 microseconds, if currents are 1200% or greater. Tripping is designed to occur between 25 microseconds and 1 millisecond for load currents between 800% and 1200% rated current. A thermal memory is utilized to shorten the trip time. The power controllers are designed to never trip if the load current is less than 110% and always trip if greater than 145%.

Kilovac (15 Amp) - Kilovac provided three remote power controllers, part number FSCM 18741 EPC3. The power controllers are a combination of a 15 amp power controller (P/N EPC-2) and a 65 amp relay (P/N AP-22). The relay can make 50 amps, carry 65, and break 200 amps 50 times. The devices were tested as 15 amp devices because of the interrupt control circuit. They operate at 270 volts dc nominally, with 300 volts dc maximum continuous voltage and 360 volt maximum transient. These devices are vacuum relays in a single pole, single throw, normally open, double break configuration. At 28 volts dc, the power controllers have a specified operate time of 18 milliseconds (including contact bounce) and a release time of 10 milliseconds. The controllers require a 28 volt dc coil voltage with a current draw of 580 milliamps nominal at 25° Celsius. The power controller's electronic circuitry required a 5 volt dc bias with a current draw of 40 milliamps. The power controllers provided both a trip and flow signal output. An I^2T integral curve is given for a step overload current for the interval 138% to 1000%. The trip time is calculated according to the following equation:

$$(T_t)=(W_t/R)/(IL^2-IO^2)$$

Where:

T_t=Trip-out time

W_t/R=10,000 (Watt)(Sec)/Ohm

IL=Overload Current (Amps)

IO=Device Rated Current (Amps)

The devices will not trip if the load current is less than or equal to 115% rated current. They will trip within an hour if the load current is greater than or equal to 138% of rated current.

Eaton (40 Amp) - Eaton provided three power controllers of the "SM" series. The devices are rated at 250 amps continuous and 1500 amps rupture. In order to use the power controllers in the MCAIR test setup, Eaton modified the devices to be set to a continuous rating of 40 to 150 amperes. A dial was placed on the outside of the contactor case to enable the tester to set the desired load rating. The contactors were tested as 40 amp continuous load devices. They are rated for operation at 270 volts dc nominal with 475 volts dc maximum. The contactors are bi-directional power controllers which are configured as single pole, single throw, double break devices. They are designed for an operate time of 35 milliseconds maximum, a release time of 25 milliseconds maximum, and have a contact bounce duration no greater than 5 milliseconds maximum. The controllers required a 28 volt dc coil voltage with a current draw of 9.8 amps maximum for 65 milliseconds. They provided both trip and flow status output signal. The power controllers are designed to utilize an integral for circuit protection; however, upon our request, are using an instantaneous trip curve, which provides a trip time of 0.255 to 0.44

seconds, which can be set using the added external dial. All MCAIR tests were run with the current dial set on 50, in order to use it as a continuous 40 ampere device, without having spurious trips caused by inrush or noise on the line. The device also incorporates voltage sensing and will trip due to an over voltage condition at 490 volts dc.

Hartman (40 Amp) - Hartman provided three power controllers, part number AHEV-775-1. The controllers are rated at 40 amps continuous and 300 amps interrupt. They are designed to operate at 270 volts dc nominal and at MIL-STD-704D power transients. They are configured as single pole, single throw, normally open, double break devices. The operate time was specified as 35 milliseconds maximum. The release time was specified as 25 milliseconds maximum with a contact bounce duration no greater than 2 milliseconds. The power controllers required a 28 volt dc coil voltage with a 3.0 amp in-rush and a 4.0 amp hold current. The control voltage was 5 volts dc nominal. These controllers provided a trip, flow, and failure status output signal. Two trip points on the trip curve are: at 75 amps, the device will not trip; at 100 amps, the device will trip in 25 milliseconds; the device will not switch unless a pulse of at least 2 milliseconds is applied.

The test harnesses consisted of seven parallel wires with a finished harness length of 48±1 inches. A black Nomex lacing cord (MIL-T-43435B, Type IV, Finish D) was used to secure the harnesses in the wire arrangement shown in Figure 2.

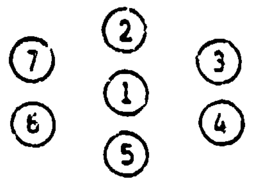


FIGURE 2 - WIRE ARRANGEMENT WITHIN THE HARNESS

The harnesses were fabricated by cutting seven wires to a length of approximately 54 inches. The wires were placed in the appropriate center locations of two 19 socket Burndy connectors (P/N GOA16-19SNE), which were held firmly in two vises 51 inches apart. The wires also passed through a third connector which was allowed to slide freely along the length of the harness between the two fixed connectors. This connector was used to assure parallel orientation of the wires when securing the string ties to the harness. The first Nomex string tie was securely placed one half inch from one of the connectors by tying a square knot on top of a clove hitch. The string ties were placed at one inch intervals for the first seven inches from the shorting end of the harness, then every two inches for an additional 36 inches. The remaining section of the harness was left untied. One end of the harness was cut at the connector where string ties are located at one inch intervals using a pair of Klein pliers (P/N 63050). The opposite end was cut to achieve a final harness length of 49 inches. This end of the harness had one quarter inch of the insulation removed and was terminated with spade terminals. Each wire was identified by numbers 1 through 7.

Each set of three power controllers was mounted on a 13 x 17 x 2 inch aluminum chassis for interchangeability within the test setup. A general schematic of the chassis configuration is shown in Appendix E with additional schematics illustrating how each individual power controller type was configured into the chassis design. Each of the larger packaged power controllers was isolated from the others and the chassis by placing a sheet of 0.125 inch Neoprene under the controllers and securing them to the chassis using nylon screws. The smaller packaged controllers were secured to a sheet of perforated epoxy glass with nylon screws. The sheet of perforated epoxy was then mounted to the chassis by one inch spacers. Photographs of the finished chassis are shown in Appendix F.

3.4 Test Equipment:

The power source used was a 270 volt dc, 30,000 watt, Westinghouse Electric Corporation Generator (modified AV-8B Generator) (P/N ED408067-001) with corresponding Generator Control Unit (P/N ED408068-001). The Generator Control Unit was configured to current limit the output of the generator to approximately 289 amps for five seconds before the Generator

Control Unit removed the Exciter Field Current and opened the Main Line contactor. The Main Line Contactor was either a Hartman (Model# A-75JD) 270 volt dc Power Contactor (S/N CH-83865) or a Kilovac (Model# 7RE2421-01) Vacuum Relay which was used to initiate the dry arc propagation test. The Main Line Contactors were interchanged by exchanging the +270 volt dc power cable from the generator terminal to the input of the main line contactors. A Jack and Heintz Power Contactor (Model# 50086-001) was placed in series with the circuit as a fail safe in case of any emergency (it remained closed until required). Two lights were attached to the backboard to indicate whether the generator was "on line" and when power was applied to the harness through the power controllers. Electrical schematics and mechanical drawings of the protected harness test setup are presented in Appendix B.

The test was designed to monitor the currents in each of the powered conductors within the harness corresponding to each individual power controller. Wires #2, #4, and #6 had 200 amp, 50 millivolt, Weston shunts placed in series with the corresponding conductors. The generator output current and generator return current were also monitored using Weston 450 amp, 50 millivolt, shunts. These differential signals were converted to single ended signals by the use of Preston Instrumentation Amplifiers and recorded on one of the two Soltec Signal Memory Recorders used. The eight channel Soltec (MD 117327) was used to capture high speed transients in the current transducers while an additional 16 channel Soltec (MD

117620) was used to monitor each individual controller's status signals in response to the short circuit. The instrumentation list for the 8 and 16 channel Soltecs is shown in Tables 5 and 6 corresponding to the signals acquired. A Fluke Y8100 AC/DC Current Probe (MD 040007) was used to trigger both Soltecs simultaneously while also capturing a filtered current value for the generator output current. The generator output voltage was recorded on the Soltec through a 10:1 voltage divider located at the terminals of the generator. The 16 channel Soltec was configured for a sample rate of 0.1 milliseconds for 65,536 samples per channel with a 12.5% pre-trigger delay, for a total test recording time of 5.7 seconds. The sample rate of the 8 channel Soltec was typically 1 micro-second for a total test recording time of 57 milliseconds. The sample rates were decreased after each initial test to increase the resolution of the signals acquired. All recorded data was stored on 5 and a quarter inch disks. Schematics of the dry arc propagation test setup with power controllers for circuit protection are shown in Appendix B.

TABLE 5 - INSTRUMENTATION LIST FOR 8 CHANNEL SOLTEC

SOLTEC CHANNEL	PARAMETER MEASURED	TRANSDUCER	AMPLIFIER GAIN	AMPLIFIER BANDWIDTH
1	PC-1 Current	Weston Shunt 200 Amp = 50 mV (MD 142486)	Preston Amplifier 20 (MD 071648)	10,000 Hz
2	PC-2 Current	Weston Shunt 200 Amp = 50 mV (MD 109154)	Preston Amplifier 20 (MD 071653)	10,000 Hz
3	PC-3 Current	Weston Shunt 200 Amp = 50 mV (MD 109152)	Preston Amplifier 20 (MD 071638)	10,000 Hz
4	Generator Output Current	Weston Shunt 450 Amp = 50 mV (MD 140729)	Preston Amplifier 20 (MD 071662)	10,000 Hz
5	Generator Return Current	Weston Shunt 450 Amp = 50 mV (MD 140730)	Preston Amplifier 20 (MD 071661)	10,000 Hz
6	Generator Output Current	Fluke Y8100 Current Probe (MD E040006)	----	---------
7	Load Voltage	10:1 Voltage Divider	----	---------
8	Generator Output Voltage	10:1 Voltage Divider	----	---------

TABLE 6 - INSTRUMENTATION LIST FOR 16 CHANNEL SOLTEC

SOLTEC CHANNEL	PARAMETER MEASURED	TRANSDUCER	AMPLIFIER GAIN	AMPLIFIER BANDWIDTH
1	PC-1 Current	Weston Shunt 200 Amp = 50 mV (MD 142486)	Preston Amplifier 20	10,000 Hz (MD 071648)
2	PC-2 Current	Weston Shunt 200 Amp = 50 mV (MD 109154)	Preston Amplifier 20	10,000 Hz (MD 071653)
3	PC-3 Current	Weston Shunt 200 Amp = 50 mV (MD 109152)	Preston Amplifier 20	10,000 Hz (MD 071638)
4	PC-1 Status	------------	----	---------
5	PC-2 Status	------------	----	---------
6	PC-3 Status	------------	----	---------
7	PC-1 Trip	------------	----	---------
8	PC-2 Trip	------------	----	---------
9	PC-3 Trip	------------	----	---------
10	PC-1 Failure	------------	----	---------
11	PC-2 Failure	------------	----	---------
12	PC-3 Failure	------------	----	---------
13	PC-1 Control	------------	----	---------
14	PC-1 Control	------------	----	---------
15	PC-1 Control	------------	----	---------
16	Generator Output Current	Fluke Y8100 Current Probe (MD E040006)	----	---------

The harness mounting fixture consisted of a 60 x 36 x 0.5 inch plywood backboard painted with a high temperature, gray epoxy resin based primer to make the board flame resistant. A 36 x 24 x 0.5 inch Bakelite board was placed beneath the test setup to collect any molten or burning debris. Two 7 x 4 inch Bakelite collars with 0.3125 inch diameter holes for the 12 gauge harnesses and 0.15625 inch diameter holes for the 22 gauge harnesses were made to hold the harness in place, six inches from the backboard. The top Bakelite collar was fixed in position at fifteen inches beneath the seven terminal Jones strip from where power to the harness was applied according to Table 7. The lower Bakelite collar was attached to a 0.375 inch threaded drill rod to make its position adjustable. The lower collar was vertically positioned six inches from the actual shorting end of each harness.

TABLE 7 - HARNESS POWER ASSIGNMENT

WIRE NUMBER	POWER SOURCE
1	- 270 Vdc
2	+ 270 Vdc
3	- 270 Vdc
4	+ 270 Vdc
5	- 270 Vdc
6	+ 270 Vdc
7	- 270 Vdc

A copper dust applicator was fabricated to apply a thin even layer of copper dust to the shorting face of the harness. The 2 x 6 x 0.25 inch plate of low carbon, precision ground steel had a 0.25 inch diameter hole for the 22 gauge harnesses and a 0.3125 inch diameter hole for the 12 gauge harnesses each drilled to a depth of 0.015±0.001 inches. The base of the hole was machined flat to within 0.001 inches.

The Dry Arc Propagation tests were recorded on one inch video tape (30 frames per second) and high speed 16 mm film (400 frames per second) to provide a record of any arcing or flaming of the test harnesses.

Photographs and schematics of the protected harness test setup are presented in Appendix B.

The test equipment used for the power controller functional tests were the 8 channel Soltec Signal Memory Recorder (MD 117327) and a Fluke Digital Multimeter (MD 136618). The tests utilized resistive loads that were configured from a load bank with a Motorola MR876 diode placed across the load. The diode was used for suppression of any inductance that may be present in the load bank resistors. A Hewlett-Packard 8011A Pulse Generator (MD 075016) was used to supply the control voltages to the power controllers. A NJE DC Power Supply (MD 078146), Model SVC40-20, was used as the 28 volt dc bias (coil) supply. The 5 volt dc bias was supplied by a Power Designs Inc. Transistorized Power Supply (MD 057065).

The tests were conducted at MCAIR's Electrical System's Generator Testing Laboratory with exhaust fans on. All personnel were in the control room during the dry arc propagation tests to avoid contact with flying molten debris and allow the exhaust fans to eliminate the potentially toxic gases.

3.5 Test Procedure:

Functional tests were performed on the power controllers initially and after each subsequent dry arc propagation test. The controllers were tested to either MIL-P-81653C or MIL-R-28750B for the solid state power controllers and to MIL-R-6106J for the electromechanical power controllers. Three basic tests were chosen as functional tests from each military specification:

MIL-P-81653C

- 4.8.7.2 Turn-On and Turn-Off Time
- 4.8.7.6 Voltage Drop
- 4.8.7.9.1 Current Limiting
- 4.8.7.9.2.a Trip Time

MIL-R-28750B

- 4.7.7.7 Turn-Off Time
- 4.7.7.8 Turn-On Time
- 4.7.7.10 Output Voltage Drop

MIL-R-6106J

- 4.7.4 Contact Bounce, Operating and Release Times
- 4.7.7 Contact Voltage Drop

These tests were chosen to ensure proper operation of the power controllers after each arc propagation test and to detect if any degradation had occurred.

3.5.1 Functional Test Procedures for ILC Data Device Corp. and Texas Instruments:

The tests performed on the Texas Instrument's and ILC Data Device Corporation's power controllers were conducted according to MIL-P-81653C, General Specification for Solid State Power Controllers.

The Turn-On and Turn-Off Time Test was conducted according to paragraph 4.8.7.2 of MIL-P-81653C, using a rated control signal of 5 volts. The load was configured to 100% of the power controller's rated current and instrumentation leads were attached to the Soltec. The Soltec recorded the control voltage, status signal, and the load voltage through a 10:1 voltage divider and triggered off the rising edge of the control signal. A schematic of the test configuration is included in Appendix B. With proper bias voltages and 270 volts dc applied, a 5 volt pulse was applied to the control input of the controller by a Hewlett-Packard 8011A Pulse Generator. The turn-on time was defined as the time interval from the control signal transition high to approximately 50% of the load voltage. The turn-off time was defined as the time interval from the control signal transition low to approximately 50% of the load voltage. The modification to use the control signal transition instead of the minimum turn-on voltage and maximum turn-off voltage was due to the fact that the rise and fall time of the pulse generator was faster than the sample rate needed to acquire the required data. The data is presented in Appendix I.

The Voltage Drop Test was conducted according to paragraph 4.8.7.6 of MIL-P-81653C. The load was configured to 100% of the power controller's rated current and the Fluke 8012A Digital Multimeter was connected at the terminals of the power controller. A schematic of the test configuration is included in Appendix B. With proper bias voltages and 270 volts dc applied, a continuous 5 volt signal was applied to the control input of the controller by a Hewlett-Packard 8011A Pulse Generator. The voltage drop was measured within 10 seconds after application of the control signal. The data is presented in Appendix I.

The Current Limiting Test was conducted according to paragraph 4.8.7.9.1 of MIL-P-81653C. This test was only conducted on the Texas Instruments power controllers and not on ILC Data Device Corporation's. The load was configured for a short circuit. The Soltec recorded the control voltage, trip signal, and the current through the power controller by a Weston 450 amp, 50 millivolt shunt. The Soltec triggered off the rising edge of the control signal. A schematic of the test configuration is included in Appendix B. With proper bias voltages and 270 volts dc applied, a 5 volt step voltage was applied to the control input of the power controller by a Hewlett-Packard 8011A Pulse Generator. The peak let through current detected and the current limit levels were recorded. The data is presented in Appendix I.

The Non-Repetitive Trip Time Test was conducted according to paragraph 4.8.7.9.2.a of MIL-P-81653C. The load was configured to 300% of the power controller's rated current and instrumentation leads were attached to the Soltec. The Soltec recorded the control voltage, trip signal, and the load voltage through a 10:1 voltage divider and triggered off the rising edge of the control signal. A schematic of the test configuration is included in Appendix B. With proper bias voltages and 270 volts dc applied, a 5 volt step voltage was applied to the control input of the power controller by a Hewlett-Packard 8011A Pulse Generator. The sample rate was varied to acquire the highest resolution possible while also capturing the required data. The trip time was defined as the time interval from approximately 90% of the rising edge of the load voltage to 50% of the trip signal. Since the status signals for the ILC Data Device Corporation's power controllers did not function properly, current duration through the power controller was recorded instead of trip time. The data is presented in Appendix I.

3.5.2 Functional Test Procedures for Teledyne Solid State:

The tests performed on the Teledyne Solid State power controllers were conducted according to MIL-R-28750B, General Specification for Solid State Relays.

The Turn-Off and Turn-On Time was conducted according to paragraphs 4.7.7.7 and 4.7.7.8 of MIL-R-28750B, respectively. The load was configured to 100% of the power controller's rated current and instrumentation leads were attached to the Soltec. The Soltec recorded the control voltage, status signal, and the load voltage through a 10:1 voltage divider and triggered off the rising edge of the control signal. A schematic of the test configuration is included in Appendix B. With proper bias voltages and 270 volts dc applied, a 5 volt pulse was applied to the control input of the controller by a Hewlett-Packard 8011A Pulse Generator. The turn-on time was defined as the time interval from the control signal transition high to approximately 90% of the rising edge of the load voltage. The turn-off time was defined as the time interval from the control signal transition low to approximately 10% of the falling edge of the load voltage. The data is presented in Appendix I.

The Voltage Drop Test was conducted according to paragraph 4.7.7.10 of MIL-R-28750B. The load was configured to 100% of the power controller's rated current and the Fluke 8012A Digital Multimeter was connected at the terminals of the power controller. A schematic of the test configuration is included in Appendix B. With proper bias voltages and 270 volts dc applied, a continuous 5 volt signal was applied to the control input of the controller by a Hewlett-Packard 8011A Pulse Generator. The voltage drop was measured within 10 seconds after application of the control signal. The data is presented in Appendix I.

The Non-Repetitive Trip Time Test was conducted according to paragraph 4.8.7.9.2.a of MIL-P-81653C. The load was configured to 300% of the power controller's rated current and instrumentation leads were attached to the Soltec. The Soltec recorded the control voltage, trip signal, and the load voltage through a 10:1 voltage divider and triggered off the rising edge of the control signal. A schematic of the test configuration is included in Appendix B. With proper bias voltages and 270 volts dc applied, a 5 volt step voltage was applied to the control input of the power controller by a Hewlett-Packard 8011A Pulse Generator. The sample rate was varied to acquire the highest resolution possible while also capturing the required data. The trip time was defined as the time interval from approximately 90% of the rising edge of the load voltage to 50% of the trip signal. The current duration through the power controller was also determined. The data is presented in Appendix I.

3.5.3 Functional Test Procedures for Eaton, Hartman, and Kilovac:

The tests performed on the Kilovac, Eaton, and Hartman power controllers were conducted according to MIL-R-6106J, General Specification for Electromagnetic Relays.

The Contact Bounce, Operating and Release Times were conducted according to paragraph 4.7.4 of MIL-R-6106J. The load was configured to 100% of the power controller's rated current and instrumentation leads were attached to the Soltec. The Soltec recorded the control voltage, status signal, and the load voltage through a 10:1 voltage divider and triggered off the rising edge of the control signal. A schematic of the test configuration is included in Appendix B. With proper bias (coil) voltages and 270 volts dc applied, a 5 volt pulse was applied to the control input of the controller by a Hewlett-Packard 8011A Pulse Generator. The make contact bounce was defined as the time interval from the first make to the final make of the contacts. The operate time was defined as the time interval from the control signal transition high to the final make of the contacts observed on the load voltage. The break contact bounce was defined as the time interval from the first break to the final break of the contacts. The release time was defined as the time interval from the control signal transition low to final break of the contacts observed on the load voltage. The data is presented in Appendix I.

The Contact Voltage Drop Test was conducted according to paragraph 4.7.7 of MIL-R-6106J. The load was configured to 100% of the power controller's rated current and the Fluke 8012A Digital Multimeter was connected at the terminals of the power controller. A schematic of the test configuration is included in Appendix B. With proper bias (coil) voltages and 270 volts dc applied, a continuous 5 volt signal was applied to the control input of the controller by a Hewlett-Packard 8011A Pulse Generator. The contact voltage drop was measured within 10 seconds after application of the control signal. The data is presented in Appendix I.

The Non-Repetitive Trip Time Test was conducted according to paragraph 4.8.7.9.2.a of MIL-P-81653C. The load was configured to 300% of the power controller's rated current and instrumentation leads were attached to the Soltec. The Soltec recorded the control voltage, trip signal, and the load voltage through a 10:1 voltage divider and triggered off the rising edge of the control signal. A schematic of the test configuration is included in Appendix B. With proper bias (coil) voltages and 270 volts dc applied, a 5 volt step voltage was applied to the control input of the power controller by a Hewlett-Packard 8011A Pulse Generator. The sample rate was varied to acquire the highest resolution possible while also capturing the required data. The trip time was defined as the time interval from approximately 90% of the rising edge of the load voltage to 50% of the trip signal. The current duration through the power controller was also determined. The data is presented in Appendix I.

3.5.4 Dry Arc Propagation Test Procedure:

The test specimen was placed in the setup by securing the appropriate spade terminals to the seven terminal Jones strip corresponding to the power assignments of Table 7. The harness was positioned in the Bakelite collars and the lower collar was adjusted to 7±0.25 inches from the end of the test harness. After positioning the harness within the setup, one inch of the harness was cut off using a pair of Klein pliers (P/N 63050) that resulted in a quarter of an inch of harness extending beyond the last string tie. The harness end was trimmed using sharp scissors to assure that all wires were cut flush with one another. The appropriate diameter hole of the copper dust applicator was filled with purified grade metal copper (electrolytic dust). A single edged razor blade was used to smooth the dust flush with the face of the applicator. The shorting end of the harness was dipped into the copper dust with the applicator perpendicular to the harness to ensure an even application. After application, the face of the harness was checked by use of a mirror to ensure that all conductors were evenly coated with copper dust. If not, the copper dust applicator was refilled and reapplied to the harness end until the entire shorting face of the harness was uniformly covered. Care was taken to ensure that copper dust was applied only to the face of the harness and not around the edges of the insulation.

The test commenced by bringing the generator speed up to approximately 4050 revolutions per minute. The power controllers were placed in their conduction state (closed) by applying a 5 volt control signal. The video equipment was started and the instrumentation was armed to trigger off of any generator output or return current. The Hartman or Kilovac main line contactor was closed to initiate the arc propagation test by supplying power simultaneously to all powered wires in the harness. Power was applied for a minimum of five seconds before the generator was brought off line either automatically or manually. If the short circuit continued for more than five seconds, the generator control unit automatically shut off the generator by removing the exciter field current and opening the main line contactor. If arcing stopped prior to the five seconds, the generator was brought off line manually. The data acquired was stored on 5 and a quarter inch disks. A minimum of five minutes elapsed after completion of the test before personnel were permitted to enter the test area due to toxic gases generated as a result of the test.

The power initiation was modified for ILC Data Device Corporation's power controllers. Instead of initiating the arc with the main line contactor, the arc was initiated with Silicon Controlled Rectifiers (SCR's). The SCR's were placed between the power controllers and the test harness. See Appendix B for a circuit diagram. The test commenced by closing the main line contactor, placing the controllers in their conduction state (closed) by applying a 5 volt control signal, and finally activating the SCR's to apply power to all three powered wires in the harness simultaneously. This modification was required because the ILC Data Device Corporation power controllers will not close into the conduction state without 270 volt dc power available at the input.

For each dry arc propagation test, the current duration through each power controller and the delay time of the trip signal was determined. The current duration through each power controller was determined by measuring the first instance of current through the power controller to the final transition to zero current. The delay time of the trip signal was defined as the time interval between the trip signal transition to when the current goes to zero. A negative delay time means that the trip signal was asserted prior to removal of current to the load. Conversely, a positive delay .ne means that the trip signal was asserted after the removal of the current from the load.

Each set of power controllers was tested once with each insulation construction, for a total of thirty-six tests.

3.6 Test Results:

The harnesses were inspected for physical phenomenon such as carbonization of the insulation, length of charring or black carbon residue on the harness, exposed or recessed conductor length, and the amount of harness consumed by the test. The harness test data is presented in Appendix G. Appendix G also includes the results from the dry arc propagation test, trip time of the controllers and delay time of the trip output signal. Photographs were taken of the test end of the harness after removal from the test setup and are presented in Appendix H. The video provided information about the smoke, secondary fire, and presence of arcing. The functional test data acquired from the power controllers is included in Appendix I.

3.7 Discussion of Test Results:

This test measured the ability of an insulation construction and a power controller to function as a system to inhibit or eliminate arc propagation during short circuit conditions in a 270 volt dc power distribution system. Test results showed that the power controller, and not the insulation construction, was the key which inhibited arc propagation. Patterns of arc propagation and/or inhibition can be attributed to the six power controllers tested.

The Teledyne Solid State and Texas Instruments (TI) solid state power controllers had similar patterns. Both had very consistent trip times with an average current time duration of 0.40 milliseconds with the Teledyne power controllers and 0.94 milliseconds with the Texas Instruments power controllers. There was no conductor consumed, insulation charred, or conductor exposed or recessed in any of the test harnesses. The only visible damage was a slight darkening at the face of some conductors and some minimal strand fusing on some conductors. In some cases, there was visible copper dust remaining on the face of the conductor. These two solid state power controllers reacted quickly enough to prevent any propagation of the arc along the harness.

ILC Data Device Corporation (DDC) provided the third set of solid state power controllers. The trip times were not as consistent with the DDC controllers as with the other two solid state power controllers. The average current time duration was 28.62 milliseconds with a minimum of 3.37 milliseconds and a maximum of 78.40 milliseconds. There was minimal wire consumed in two of the harnesses with approximately a quarter inch of insulation charred. There was also minimal conductor recessed or exposed in five out of six harnesses. Additional visible damage ranged from none to one quarter inch blackening of the insulation and some conductor strand fusing. Although there were more visible signs of damage with the DDC controllers than with the other two solid state power controllers, the amount of damage was very minimal.

The Eaton and Hartman electromechanical controllers functioned in similar patterns. The Hartman devices had a lower average current time duration of 90.92 milliseconds, as opposed to Eaton at 155.1 milliseconds. However, the Eaton devices were slightly more consistent in trip times than the Hartman devices. Both had average trip times greater than all three solid state devices due to the added time required to mechanically break the circuit. No wire was consumed in any of the harnesses with the Eaton controllers and minimal wire consumption was noted on two harnesses with the Hartman controllers. Some charred insulation and exposed or recessed conductor was noted on all six harnesses with both controllers. Other visible damage included some additional darkening of insulation and some strand fusing of conductors. The NEMA harness with the Hartman controllers also had conductors #2 and #3 shorted together. Even though more damage to the harnesses was incurred with these electromechanical controllers than with the solid state controllers because of the greater length of time that current flowed through the harness, these controllers were able to protect the harness by limiting the propagation of the arc.

The Kilovac electromechanical power controllers were consistent in that none of the controllers tripped in any of the tests. The average current time duration through the test harness was 733.5 milliseconds. This time was great enough to allow loss of conductor continuity in the Thermatics harness and an average of greater than one and one quarter inch of wire to be consumed. Charred insulation and minimal recessed or exposed conductor was also noted. The present design of the Kilovac device did not protect against arc propagation.

Functional tests were performed both prior to and following each dry arc propagation test to ensure that the controllers were not damaged. Tests proved proper operation in all cases except one. The DDC controller #3 was found to have been damaged during the final arc propagation test with the M81381 harness.

4.0 MANUFACTURER'S COMMENTS

4.1 Eaton:

The three units supplied by Eaton Corporation to McDonnell Douglas, St. Louis, for use in their arc propagation testing, were modifications of units presently in production. These units are rated at 270 volts dc, 250 Amps, and contain electronic current sensing in addition to status reporting and other electronic features.

The units are designed to trip in accordance with a customer supplied specification and trip-time curve. Consequently, the contactor current sensing circuit must see a sustained trip current level for six milliseconds prior to the electronics commanding the contactor to open. This feature was added to prevent "nuisance trips". Total operating times for these contactors are 35 milliseconds maximum to close and 25 milliseconds maximum to open including the six millisecond delay.

The modification made to the three test units for the McDonnell Douglas wire tests consisted of replacing a resistor in the current sensing circuit with a variable resistor. This variable resistor is mounted in the contactor header and is calibrated in twenty amp increments allowing the user to select the current level desired (from 10 to 250 Amps) for contactor trip. It should be noted that the trip time does include the six millisecond delay discussed above.

Review of the test sequences' thermal printer plots clearly shows the results of the six millisecond delay built into the current trip circuitry of the test contactors. When current was applied to the shorted wire bundle, current levels would rapidly rise and fall on each power line until an arc drawing more than the set trip current for more than six milliseconds caused a contactor to trip open. Then the second contactor would trip followed by the third. The result is an approximate event elapsed time of 60 to 90 milliseconds. (NOTE: the third contactor did not open during one test sequence since no short existed on the line.)

It is the opinion of Eaton Corporation that if the six millisecond delay discussed above is not necessary for the application of wire protection, its elimination would result in a total event elapsed time of approximately 20 to 30 milliseconds maximum. The contactors would be commanded to trip by their current sensing circuitry as soon as the set current level trip point was exceeded, resulting in minimal damage to the shorted wire.

4.2 Hartman:

Based on results of testing performed by the McDonnell Douglas/Bell Helicopter LH Team, the arc propagation test conducted at MCAIR, and Hartman's testing, the AHEV-775 contactors are proving to be reliable high voltage contactors. The AHEV-775 series contactors have successfully completed electrical life test of 50,000 cycles at rated current and voltage (40 amp - 270 volts dc). Additional testing at

Hartman has proven this design capable of nominal ratings of 60 amps at 270 volts dc and rupture levels of 500 amps 270 volts dc.

The Hartman electronics can be revised to provide I^2t protection in addition to the fault protection. The fault protection can be revised to provide relay trip times of equal to or less than 15 milliseconds while allowing 10 milliseconds of normal overload current without tripping. Wiring faults will then be cleared in 15 milliseconds or less without inadvertently reacting to normal overloads.

4.3 ILC Data Device Corporation:

ILC Data Device Corporation's SSP 21116 line is DDC's first generation 270 volt dc power controller which is similar to DDC's line of Power MOSFET Power Controllers which range from 28 volts dc to 115 volts ac and from 2 to 80 amps. The SSP 21116-015, which was used in the test, is a 15 amp 270 volt dc Power Controller with a +5 volt dc bias supply and two status output lines. The SSP 21116 uses two custom monolithics to perform all the analog monitoring and the digital status reporting required for a power controller. These devices are similar to those used in DDC's other controllers, however an error in the prototype hybrid layout kept the status lines from working properly. The controller was functioning properly, however the status reporting of its condition was not correct. A noise condition present on the 270 volt dc generator, which was not on the laboratory power supply, presented some initial coupling problems between two lines within the hybrid, which will be fixed with a new layout. For this test however, a capacitor placed across the Power In line and ground was all it took to clear it up. The SSP 21116 senses the current with two different circuits which check for over current relative to an I^2T curve and for a fault condition of greater than a 1000%. The difference between the two circuits is the trip times, which for a fault condition is within 25 micro-seconds. Switch times this fast are capable with MOSFET switches. The SSP 21116 also incorporates a Built-In-Test (BIT) which monitors reverse current, MOSFET failure or degradation, unit over temperature and control circuit failure.

DDC is presently updating the controller to incorporate the information learned in the field.

4.4 Kilovac:

Kilovac's EPC3 remote power controller (henceforth referred to as RPC) consists of an electromechanical vacuum contactor controlled by an electronic circuit which performs input/output signal buffering/isolation, logical control, and fault detection (by means of a Hall-Effect current sensor) and fault current processing (trip curve). The latter function of the RPC's electronic circuit is the subject of this letter.

In the tests that were witnessed at McDonnell, Saint Louis, three RPC units were connected in parallel to parallel faults in a bundle from a common generator (280 amp fault regulated output). The faults were set up in the wire bundle in order to propagate an arc.

The EPC3 units were adjusted to the Over-Current Trip Curve shown on sheet 6 of Rev. 9 of the Sales Drawing for the EPC2. This graph, an illustration of MIL-C-83383/1C, is specified for a 15 Amp Remote Control Circuit Breaker, is for an entirely electromechanical device. Hence, at 1000% overload, the graph (Figure 3, Point A) indicates that trip-out may require as long as 1.2 seconds. Review of our data indicates that our present adjustment procedure tends to yield trips about this upper limit.

The arc propagation tests that were witnessed showed that (for test conditions) an arc of about 0.3 second would consume about 0.10 meters of the 22 gauge, bundle (7 wires). If the arc persisted for around 1 second, the results were catastrophic, and the entire 1 meter bundle would be damaged or consumed.

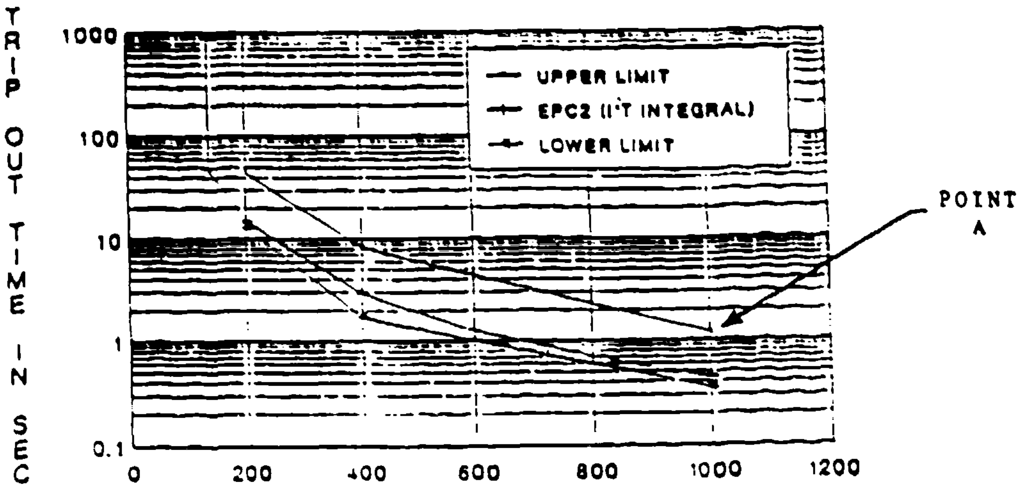
Hence the present trip-out characteristic defined by MIL-C-83383/1C (for which our device is built to) is inadequate for your application.

However, Kilovac's RPC can be readily adapted to facilitate rapid trip-out under heavy overloads and still maintain a normal I^2t characteristic to lesser overloads. It was designed with this option in mind from the start. This concept, shown in Figure 4, Point B, has been proven in our existing EPC2 breadboard circuit and is being adopted for future RPC products. In this scheme, the trip envelope is adapted from MIL-P-81653. Notice that the maximum trip time for a 1000% overload is 0.4 seconds. In fact, the trip time may be reduced to as short as two times the release time of the contactor employed in the RPC (typically 0.01 - 0.05 second, depending on the type of contactor).

In conclusion, Kilovac has developed and tested RPC units which can respond quickly to massive faults in order to interrupt power flow before catastrophic arc propagation occurs. We regret that this option was not included in the RPC units supplied for your arc propagation tests. The fast interrupt option is built into current and future RPC products and is available upon request.

REV. 2

OVER-CURRENT TRIP CURVES
CIRCUIT BREAKER FUNCTION, DC, 270V, 15A
MIL-C-83383/1C ENVELOPE FOR 15A DEVICE



NOTES:

1. The I^2T integral curve is given for a step overload current for the interval 138% to 1000%. The Trip-out time (T_t) is given by the following equation:

   $T_t = (W_t/R)/(I_L^2 - I_0^2)$ where: W_t/R = 10,000 (Watt·sec/Ohm)
   I_L = Overload Current (Amperes)
   I_0 = Device Rated Current (Amperes)

2. The EPC2 approximates the I^2T integral curve and resides within the upper and lower limits of the MIL-C-83383/1C envelope for 15A Remote Control Circuit Breaker Device.

3. Trip Threshold:

   a) No trip will occur with a sustained overload current at or below 115% of the rated device current. For the EPC2, the rated device current is 15A.

   b) Ultimate trip will occur within 1 hour for sustained overload current of 138% of the rated device current.

DIMENSIONS IN INCHES (DIMENSIONS IN PARENTHESES ARE IN MILLIMETERS) TOLERANCES EXCEPT AS NOTED xx = ± .03 xxx = ± .010 ∡ x° = ± 2° DO NOT SCALE DWG.	Kilovac	P.O. BOX 4422 Santa Barbara, CA 93140-4422	
	EPC2		
	FSCM NO. 18741	SCALE NONE	SHEET 6

FIGURE 3 - KILOVAC'S OVER-CURRENT TRIP CURVE (POINT A)

270 Vdc Remote Power Controllers

All of the relays and contactors shown in this catalog can be combined with Kilovac's exclusive hybrid electronics to create a remote power controller (RPC). An RPC functions as a relay/contactor and is also capable of sensing and interrupting an overload condition. The following figures indicate Kilovac's system architecture and typical over-current trip curve. Custom models can be built to your specific requirements upon request.

Features

- Hybrid design for smallest size and weight
- Current sensing shunt for stability over the temperature range
- Electrically isolated +270Vdc ground, +270 Vdc return and control/status common eliminating possible system problems
- TTL and CMOS compatible outputs for most flexible use
- BIT (built in test) for improved system reliability
- No temperature derating
- Meets requirements of MIL-P-81653

Fig. 1 System Architecture

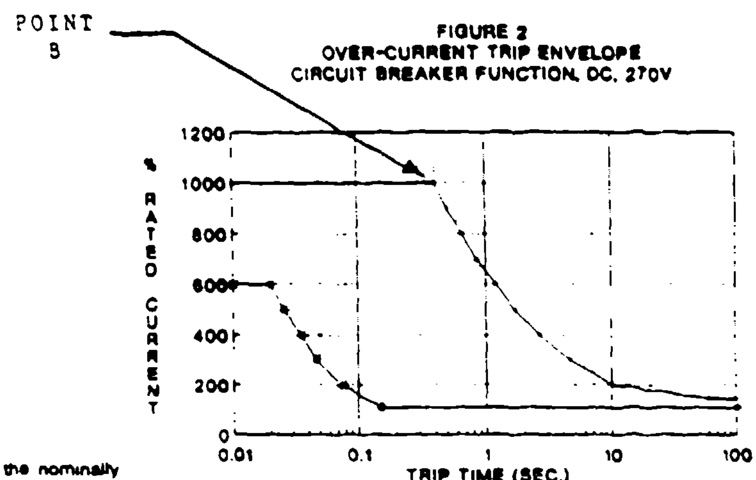


Fig. 2 Over-Current Trip Curves

Function

1 Control input, when asserted, turns the RPC on and closes the vacuum relay contacts. This signal is coupled to the internal controller by means of an optical isolator. The control signal may be TTL, CMOS, or a mechanical switch. A logic high input asserts Control and a logic low de-asserts Control.

2. Status indicators are TTL and CMOS compatible outputs. They are coupled to the internal controller by means of an optical isolator.

a) Bit/Trip indicates the state of the contactor. Bit/Trip outputs a logic high whenever the contactor is closed and a logic low whenever the contactor is open (due to either the de-assertion of external control or an internally sensed overload).

b) Status indicates current flow. Status outputs a logic low whenever greater than 10% of the nominally rated current is flowing. Status outputs a logic high whenever 10% or less of the nominally rated current is flowing.

3. The +270 Vdc ground return, +28 Vdc return, and control/status common are all isolated within the RPC. These lines may be externally connected together by the user.

4 The coil control circurtry is isolated externally using opto- isolators.

5. +28 Vdc supplies controller and coil.

6. Trip Characteristic is Trip-Free, meaning that the RPC will trip out due to a sustained overload even when the Control signal is asserted. The Trip Time vs Overload Current characteristic is a logarithmic approximation as described in Fig. 2.

NOTES:

1 The trip envelope is given for a step overload current for the domain of 138% to 1000%.

2. The RPC logarithmically approximates the ideal I^2T integral curve.

3. Trip Threshold:

No trip will occur with a sustained overload current at or below 138% of the rated device current.

FIGURE 4 - KILOVAC'S OVER-CURRENT TRIP CURVE (POINT B)

4.5 Teledyne:

The solid state power controllers supplied by Teledyne Solid State for the wire protection testing are standard catalog products. These solid state relays/remote power controllers are currently in production and have been shipped to a wide base of customers, ranging from land based systems to high reliability space applications. The VD46KKW relays used in the testing at McDonnell Aircraft are rated at 5 amps over temperature for use in MIL-STD-704D 270 volt dc power systems. These parts are available to either W or Y screening levels of MIL-R-28750. Preliminary slash sheets to MIL-R-28750 have been drafted and submitted to DESC for approval. Upon acceptance by DESC, Teledyne Solid State will begin full Military qualification for the entire product line.

4.6 Texas Instruments:

Traditional circuit protection devices rely on a bimetal to sense the resistive heating of the wire and cable and act as a thermal analog to the wire's energy content. The MS3320 time-current curve for ambient compensated circuit breakers is the commonly accepted industry standard for defining this time versus current relationship. This maintains the wire's energy below the wire damage curve and maximizes the current carrying capacity of the wire, minimizing the overall system weight. As the thermal energy of the wire can be affected by existing load conditions or prior overloads, a circuit breaker remembers the energy state of the wire and reduces the trip times accordingly when current overloads approach the wire's energy storage limit. Inherent in this approach is the "thermal memory" of the bimetal which accumulates and dissipates thermal energy in the same manner as the protected wiring.

By incorporating "thermal memory" in the SSPC design and basing the time versus current relationship on MS3320, the same design criteria can be used for aircraft circuit breakers, SSPC's, wire, and load derating. Additionally, since the MS3320 time-current curve parallels the wire damage curve it optimizes the allowed current inrush for operating aircraft loads. This is essential as many common aircraft loads produce momentary high current transients in their normal operating mode. These include lamp loads, charging capacitive loads, and motor loads. By tailoring the trip curve to the wire damage curves it is possible to handle these transients without nuisance tripping and without hazard to wiring. Without the ability to absorb these momentary current transients, instant trip devices could induce nuisance trips or require needless derating of protective devices.

The Texas Instruments design, which incorporates MS3320, has maximized the current carrying capability of the protected wire and cable. Additionally, this response has been tailored to benefit the system for the entire range of overload conditions from normal transients to short circuit conditions and has a virtually unlimited rupture capacity. This enhances the system's effectiveness by maintaining the protective advantages of traditional circuit breakers and gaining additional control and protective advantages offered by solid state technology; 270 volts dc capability, status indications, current limiting, and remote switching control.

5.0 CONCLUSIONS

The three inorganic insulations tested were not able to inhibit arcing in a 270 volt dc power system. Five of the six power controllers tested were able to inhibit or limit arc propagation in a 270 volt dc power system. The Teledyne Solid State and Texas Instrument solid state power controllers provided excellent protection in inhibiting arc propagation. The ILC Data Device Corporation solid state power controller provided good protection in inhibiting arc propagation. The Eaton and Hartman electromechanical power controllers provided moderate protection in limiting arc propagation. The Kilovac electromechanical power controller was not able to provide protection from arc propagation.

APPENDIX A

ASTM D09.16 DPAFT

OF

DRY ARC PROPAGATION TEST

Inclusive pages: 56 - 65

F-33615-89-C-5605

DRY ARC RESISTANCE AND FAULT PROPAGATION

Drafted By:
Asok Bhattacharya, Boeing
Pat Cahill, FAA
Ron Soloman, McDonnell Aircraft
Bob Waterman, Lockheed
Lynn Woodford, McDonnell Aircraft

Presented To: ASTM D 09.16

October 18, 1989

Draft Origin:

MCAIR hosted an informal meeting to develop a draft of a Dry Arc Propagation Procedure which reflects the needs of the aircraft manufacturing industry. Boeing, the FAA, and Lockheed were participants in the drafting of this procedure. It seemed desirable that the participants would be individuals who had capability to Dry Arc test with representative aircraft power systems. The meeting was held on the 29th and 30th of September. The SAE Dry Arc Propagation Procedure (Method 301) was used as a "straw man" to begin the draft. Comments from all participants were incorporated to produce the new draft which is being presented to ASTM D 09.16. It is hoped that this new draft may now be used as a "straw man" by ASTM D 09.16 to produce a Dry Arc Propagation Procedure which is functionable for all system power levels and is acceptable to all industry users.

DRY ARC RESISTANCE AND FAULT PROPAGATION

Draft written by:
Asok Bhattacharya, Boeing
Pat Cahill, FAA
Ron Soloman, McDonnell Aircraft
Bob Waterman, Lockheed
Lynn Woodford, McDonnell Aircraft

Draft prepared by: Lynn Woodford

1.0 SCOPE

This test is to be used to evaluate the resistance to arcing and the propagation of faults in a seven wire bundle. This test measures the arc duration to determine the performance of the wire insulation.

2.0 SAMPLES

2.1 Wire Specimens: Each wire bundle shall be comprised of seven identically insulated wire specimens with a minimum length of 10 inches. Longer lengths may be used to facilitate additional tests. A minimum of five tests per wire size is required. A power bundle shall consist of seven, 8 AWG wires concentrically laid and a signal bundle shall consist of seven, 20 AWG wires concentrically laid. Both power and signal bundles shall be tested to determine the performance of an insulated wire system.

2.2 Bundle Fabrication:

2.2.1 Cut seven, 20 AWG and seven, 8 AWG wires of the same insulation construction with a minimum length of 10 inches.

2.2.2 Cut all wires flush on one end (the test face) and strip off 0.25 inches of insulation on the other end. Install spade terminals or equivalent for attachment to power source(s).

2.2.3 Assemble all seven wires of the same gage as shown in Figure 1. Place the flush cut ends together . Straighten all the wires to assure parallel lay and concentricity. Tie the bundles securely with "Nomex" or equivalent tie cord every 2 inches beginning 0.25 inches from the end of the insulation at the test face until the entire length is tightly bundled and straight.

2.2.4 Label each wire in the bundle with a description of the power (see Figure 1). Label the test bundle with the insulated wire code identification. Place all labels near the power end of the specimens.

2.2.5 Connect the bundle vertically to the test fixture with the flush end down (see Figure 3).

2.2.6.1 For the 20 AWG bundle, carefully cut all seven wires flush at the test end, after installation into the test fixture. Use guillotine type wire cutters (McMaster Carr Part #4938A31 Coaxial and Fiber Optic cutters or equivalent) to get as square a cut as possible. Jagged ends do not produce repeatable results.

2.2.6.2 For the 8 AWG bundle, the bundle test face should be cut with a band saw prior to installation in the test fixture. Any excess insulation material left after cutting should be trimmed off using a sharp pair of dikes. If the bundle is being reterminated for an additional test, it will have to be removed from the fixture to cut the ends flush with the band saw.

2.2.7 Fill the recessed hole in the copper dust applicator (see Figure 2) with copper dust. Smooth the dust flush with the applicator face by using a razor blade or similar straight edge.

2.2.8 Move the copper dust applicator to coat the end of the bundle. Ensure recessed bottom of applicator is perpendicular to the bundle test face. This forms the short circuit. Caution: Do not get an excessive amount of copper dust on the sides of the bundle, but ensure that the test face is evenly covered.

2.2.9 Use a split insulating collar made of bakelite or phenolic (or similar device) to support the test specimen (see Figure 3). Close the two halves of the collar around the test bundle.

2.2.10 Insert the assembly into the jaws of a laboratory test tube clamp (or equivalent) which is supported by a laboratory test stand. See Figure 3 for test fixture set up.

3.0 EQUIPMENT

3.1 Generator and/or DC Power Supply: Use a system representative of the final application for the test specimen.

3.2 Power Contactor(s): Use power contactor(s) with a continuous rating compatible with application requirements.

3.3 Start Switch: Use a normally open, single pole, single throw switch to control the power contactor(s).

3.4 Copper Dust Applicator: One metal plate should have five 0.25 inch diameter holes and one metal plate should have five 0.75 inch diameter holes. Holes on both plates should be recessed 0.015 +/- 0.001 inch and have a flat bottom with a nominal variance of 0.0001 inches (see Figure 2).

3.5 Recording Oscilloscope: Use a Nicolet Moore #204-A or a Soltec SMR2 Transient recorder (or an equivalent of either). Recorder must be capable of measuring 0.1 msec or less.

3.6 Copper Dust: Fisher Scientific Copper Metal-Purified Grade, electrolytic dust (or equivalent).

3.7 Test Chamber: Use a test chamber which prohibits any smoke or molten copper contact with personnel conducting the test (see Figure 3). For direct viewing of the arc, a video camera and monitor are preferred. Otherwise, use special safety glasses or film to prevent eye damage.

3.8 Current Transducers: Use an Ohio Semitronics CT1.5KHT transducer and CT101H signal conditioner (or equivalent) to monitor arc current; this provides a means for measuring the time of arc duration.

3.9 Optional Equipment:

3.9.1 Video Camera: A video camera may be used to photo document the test and provide a record to time the duration of arcing and/or flaming.

3.9.2 Manual Safety Disconnect Switch: A manual 3 phase knife switch with appropriate current rating may be used (see Figure 4).

3.9.3 Resistors: 1.0 to 1.5 ohm resistors with the appropriate power rating may be used (see Figure 4).

3.9.4 Volt Meter: A volt meter to measure line voltage during the test may be used.

4.0 TEST PROCEDURE

4.1 Build test bundles per paragraph 2.0 and Figure 1. Set up equipment as required in paragraph 3.0 and Figures 3 and 4.

4.2 Turn on the power source(s).

4.3 If manual safety disconnect is used, close knife switch.

4.4 Turn on and prepare all measuring/recording equipment. Voltage recording is optional for calculating power values.

4.5 Verify that the test chamber will protect all personnel from smoke and flying debris. Ensure any visual observation of arc is by monitor or with eye protection.

4.6 Close power contactor (simultaneously for AC and DC if both are used) and keep closed for 10 seconds or until the power source protection interrupts power (whichever is least).

4.7 Open the power contactor.

4.8 Record the duration of the arc to the nearest 0.1 msec.

4.9 Prepare all recording equipment for reapplication of power for a restrike test.

4.10 Wait one minute minimum before reapplying power. Close the power contactor for 10 seconds or until the power source protection interrupts power (whichever is least).

4.11 Open the power contactor and turn off all power sources.

4.12 Record the duration of the arc to the nearest 0.1 msec.

4.13 A minimum of five tests are required for each wire gage. The wire bundle may be cut flush (ensure tie string is within 0.25 inch of the test face) on an area unaffected by the arc flash and the test rerun or a new wire bundle may be used.

4.14 Repeat steps 2.2.5 through 2.2.10 and 4.1 through 4.12 a minimum of 4 more times.

5.0 RESULTS

Report arc duration to the nearest 0.1 msec for initial arc strike and any restrike and visually observed physical phenomenon such as excessive smoke, secondary fire, carbonization of insulation, and recession of conductor into insulation.

6.0 INFORMATION REQUIRED IN DETAIL SPECIFICATION

Number of test bundles (greater than five) to be tested and maximum arc duration in msec.

7.0 PRECISION BIAS

This is a new method which has not had the benefit of any round-robin testing to determine precision.

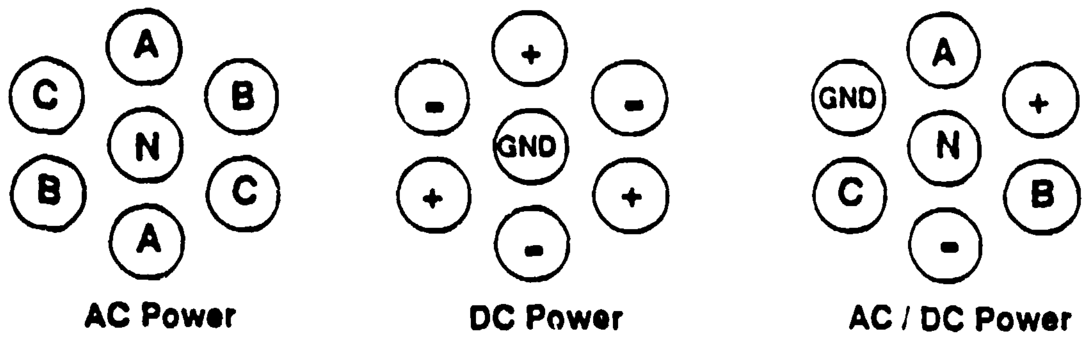
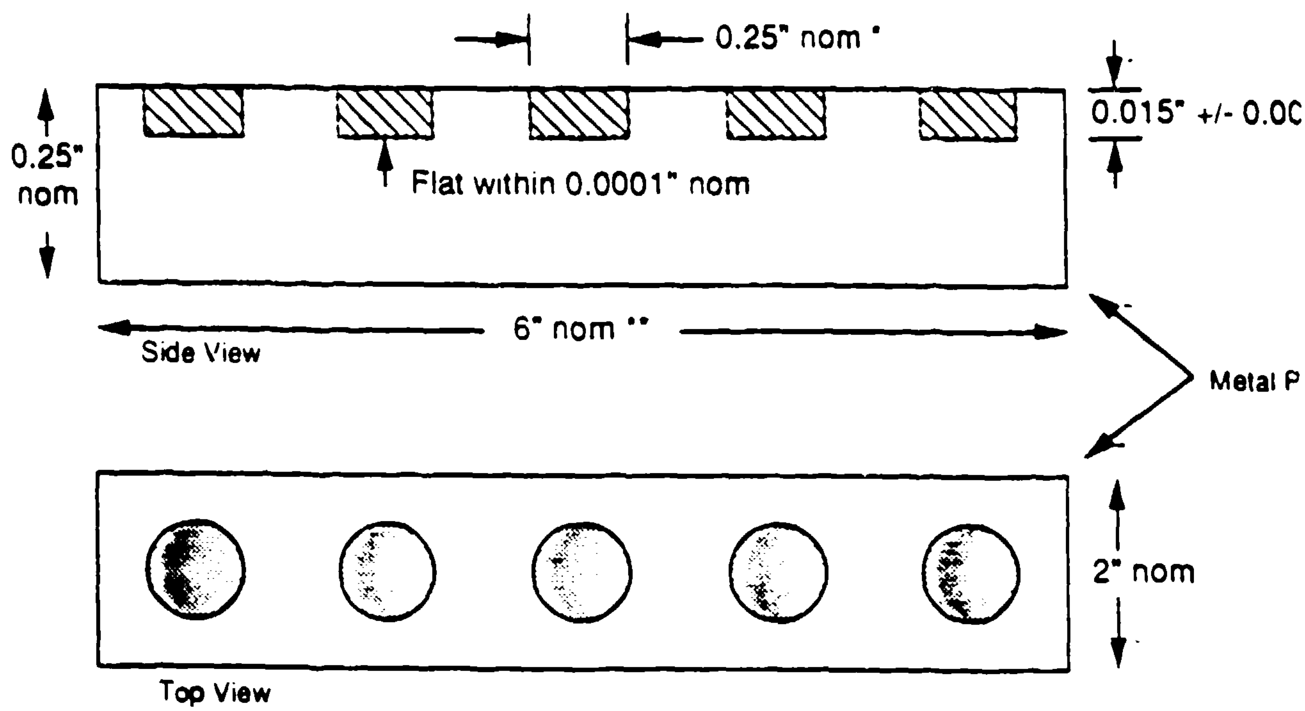


FIGURE 1. POWER ASSIGNMENT



* For 8 AWG Power Bundle, Hole Diameter Shall Be 0.75" nom.
** For 8 AWG Power Bundle, Length Shall Be 8" nom.

FIGURE 2. COPPER DUST APPLICATOR

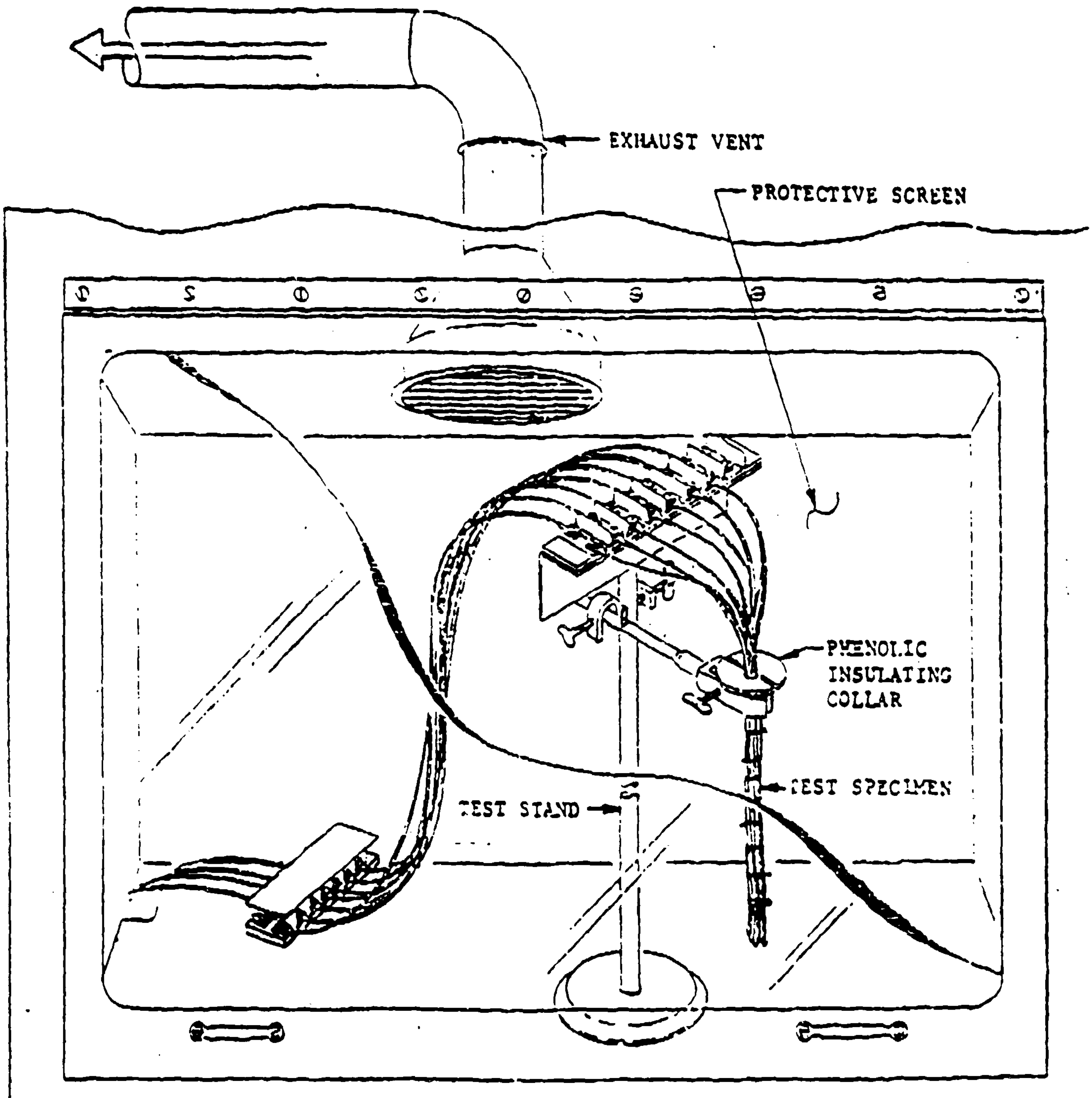


Figure 3. OVERALL TEST SET-UP OF DRY ARC TEST

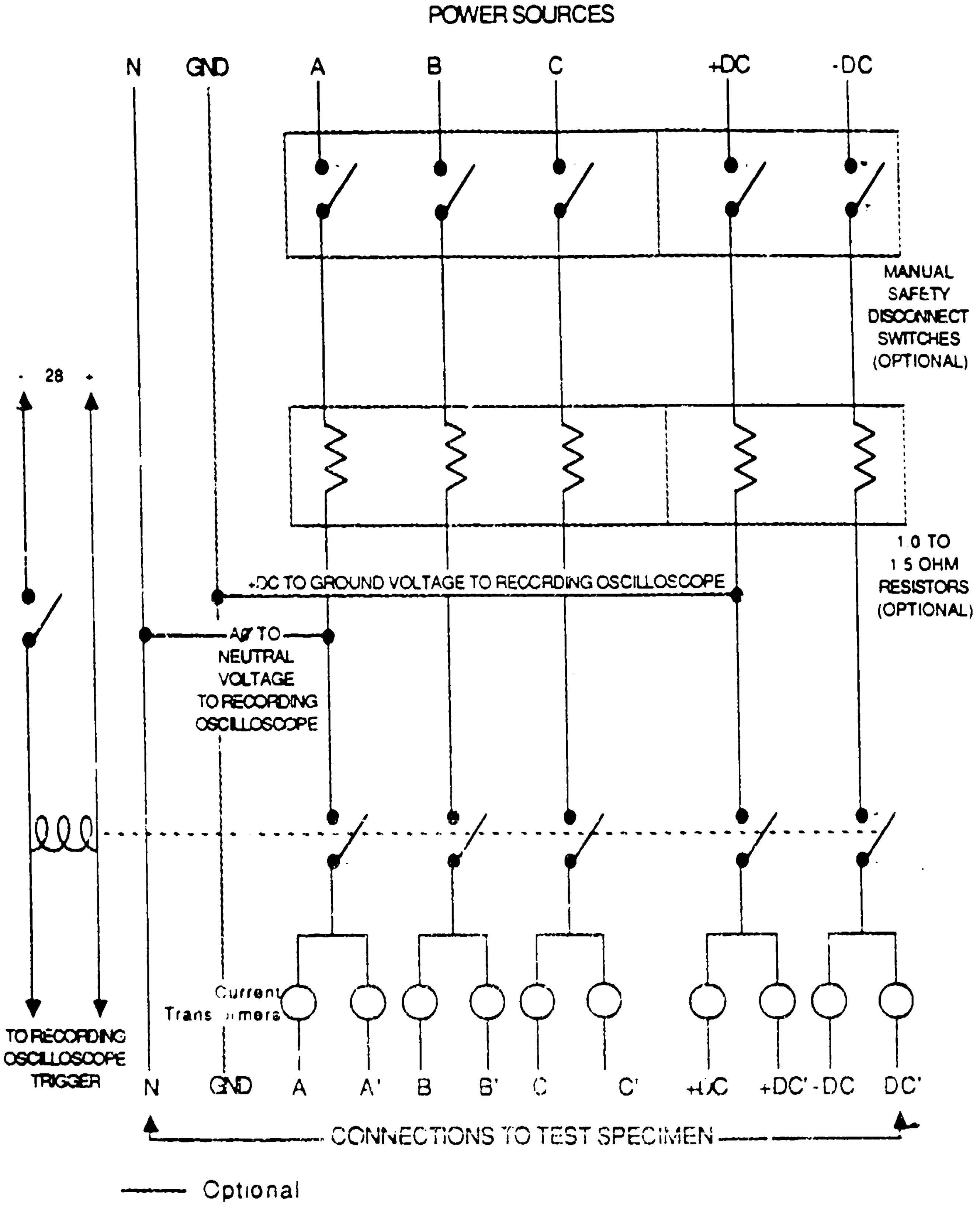


FIGURE 4. ELECTRICAL CONNECTIONS

APPENDIX B

PHOTOGRAPHS AND SCHEMATICS OF DRY ARC PROPAGATION TEST SETUPS

Inclusive pages: 67 - 74

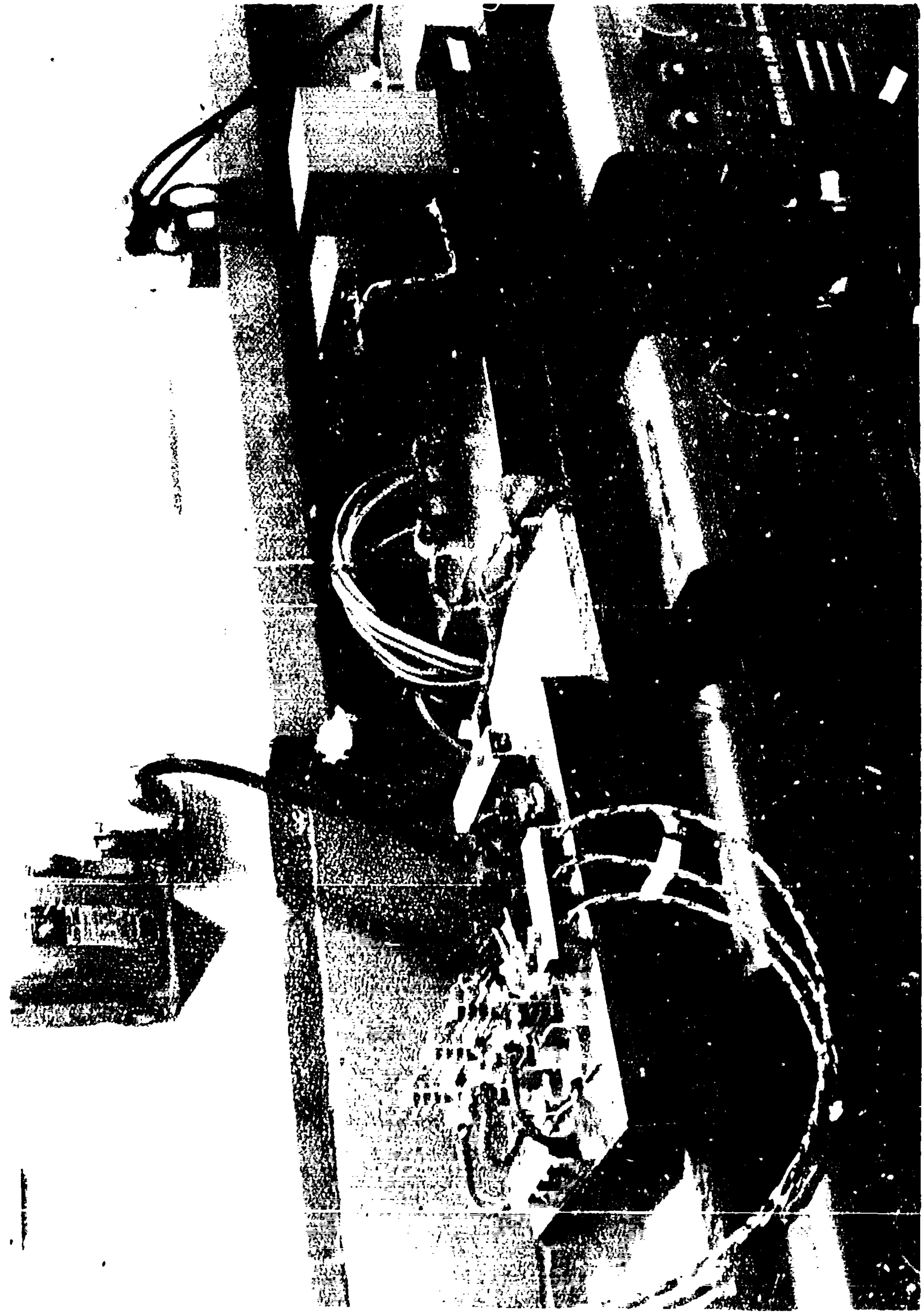


FIGURE B1 - INORGANIC DRY ARC PROPAGATION TEST SETUP

FIGURE B2 - TEST HARNESS HOLDING FIXTURE

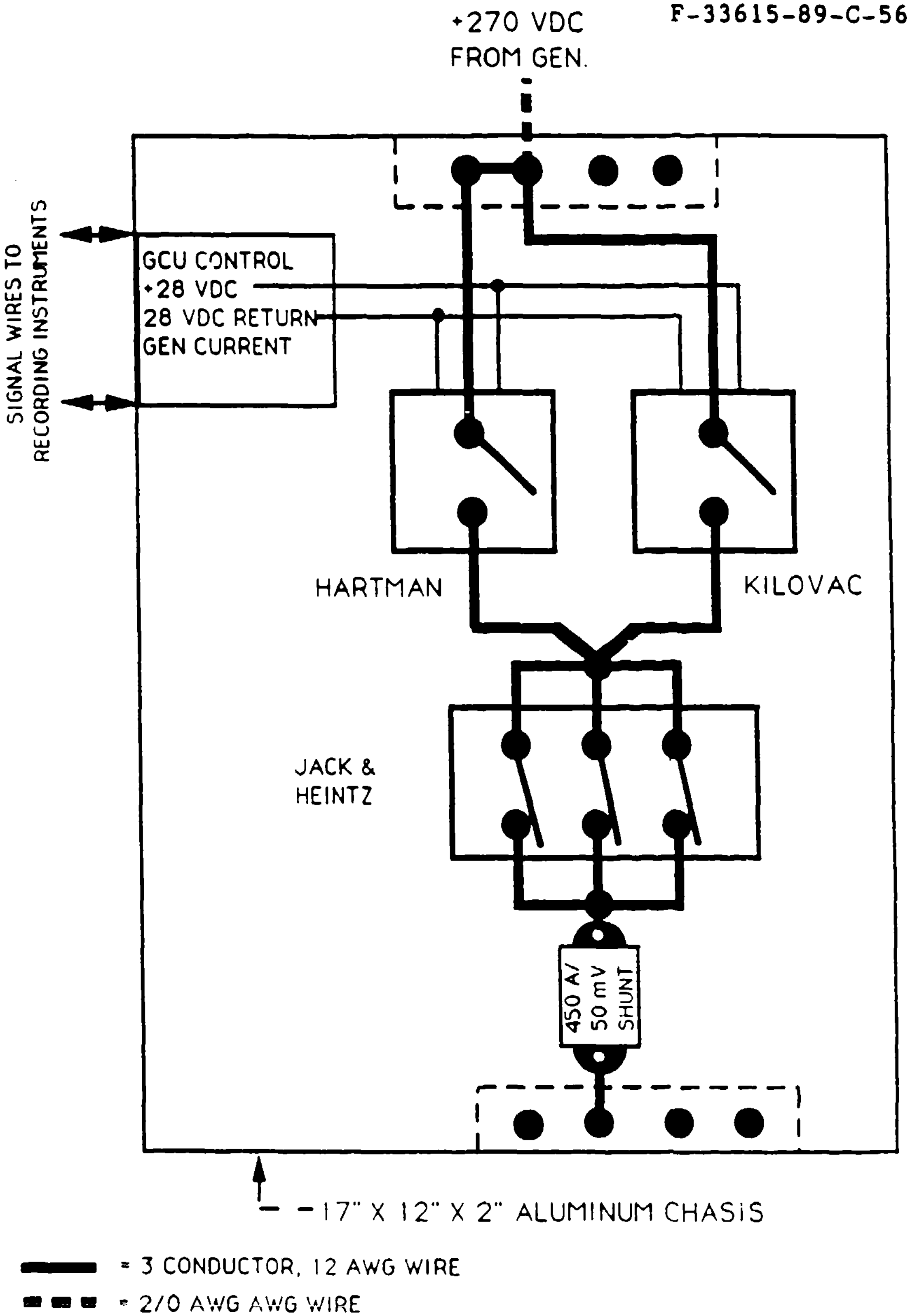


FIGURE B3 - SCHEMATIC OF MAIN LINE CONTACTOR CHASSIS

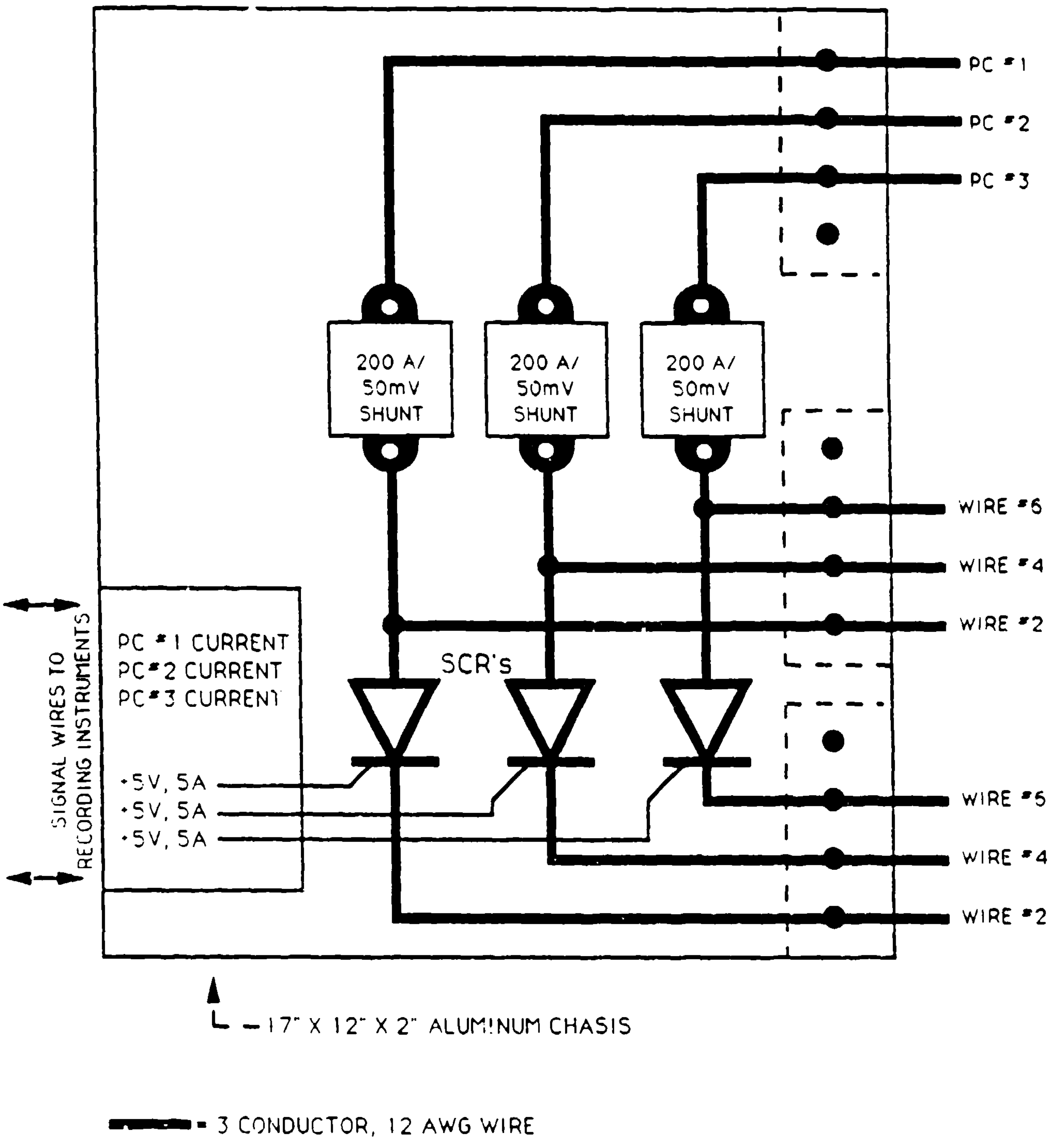


FIGURE B4-SCHEMATIC OF INSTRUMENTATION CHASSIS

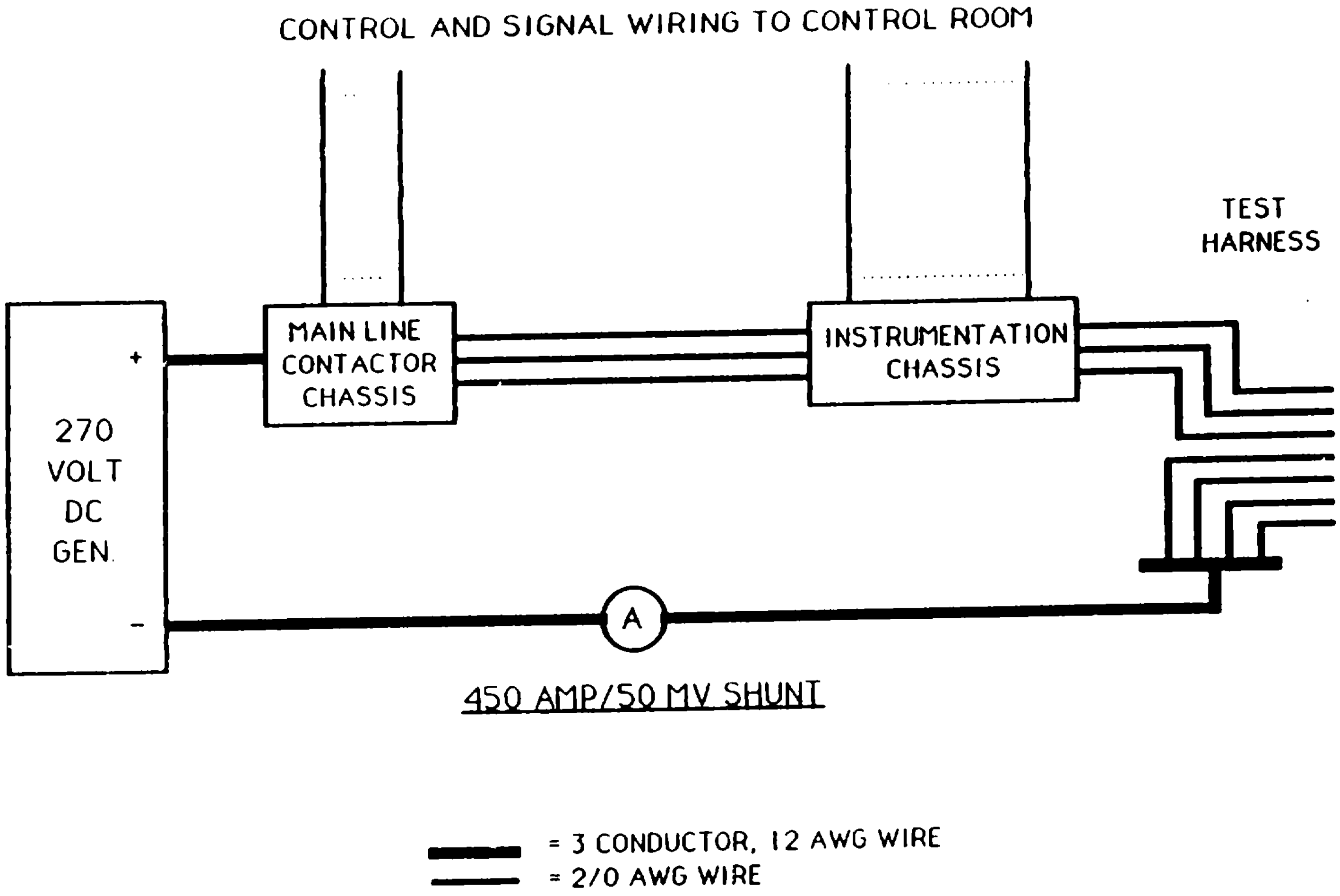


FIGURE B5-INORGANIC DRY ARC PROPAGATION TEST CONFIGURATION

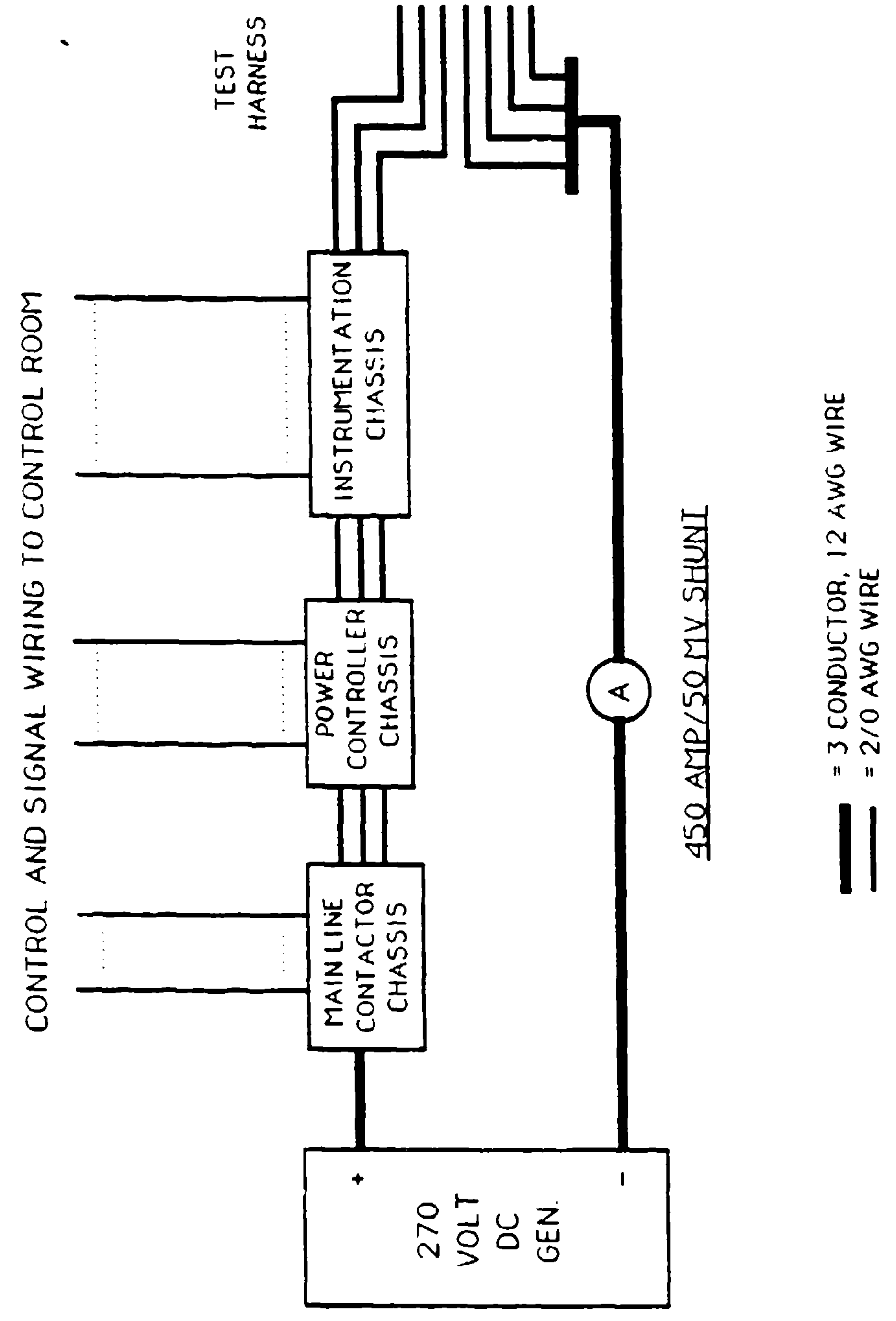
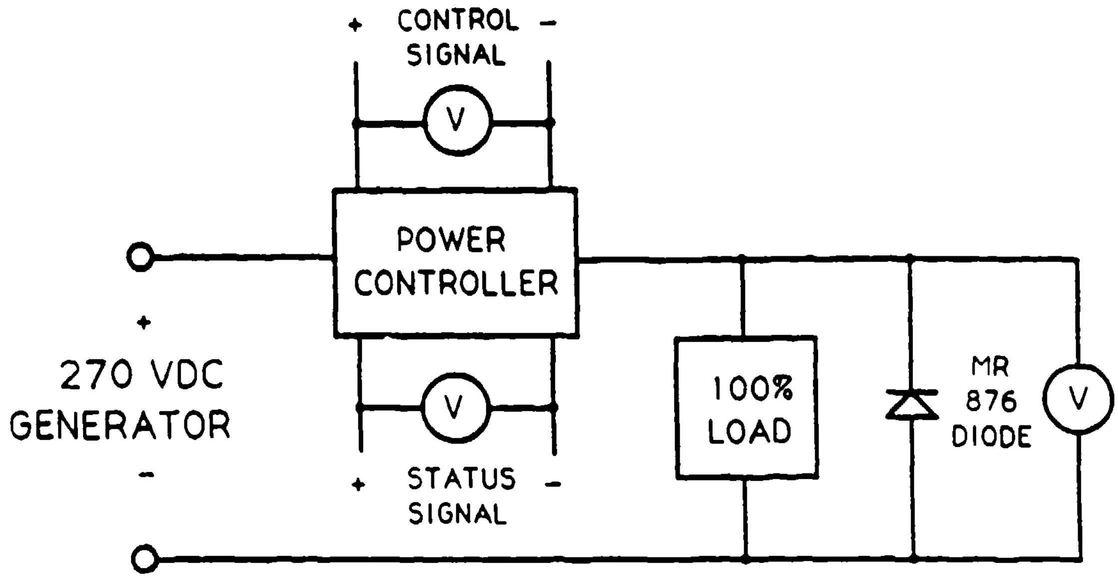
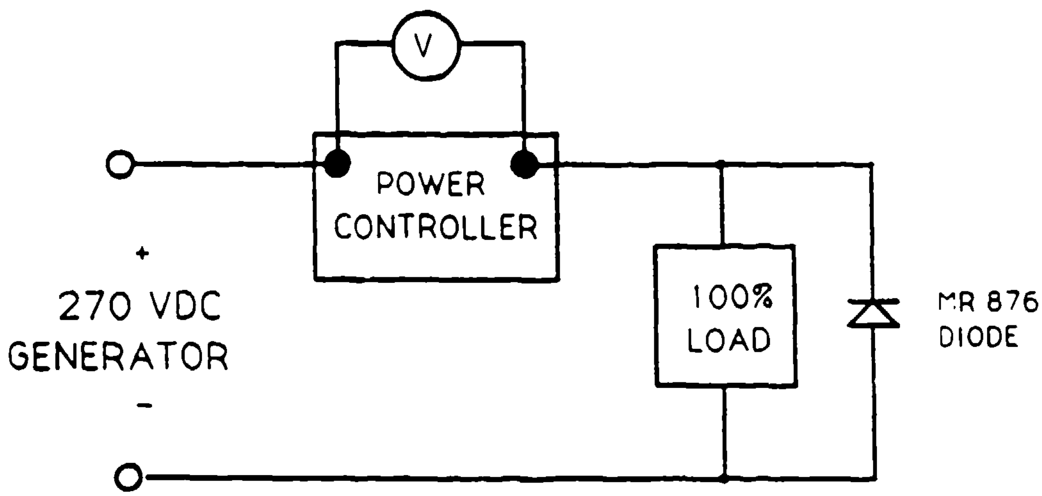


FIGURE B6-POWER CONTROLLER DRY ARC PROPAGATION TEST CONFIGURATION



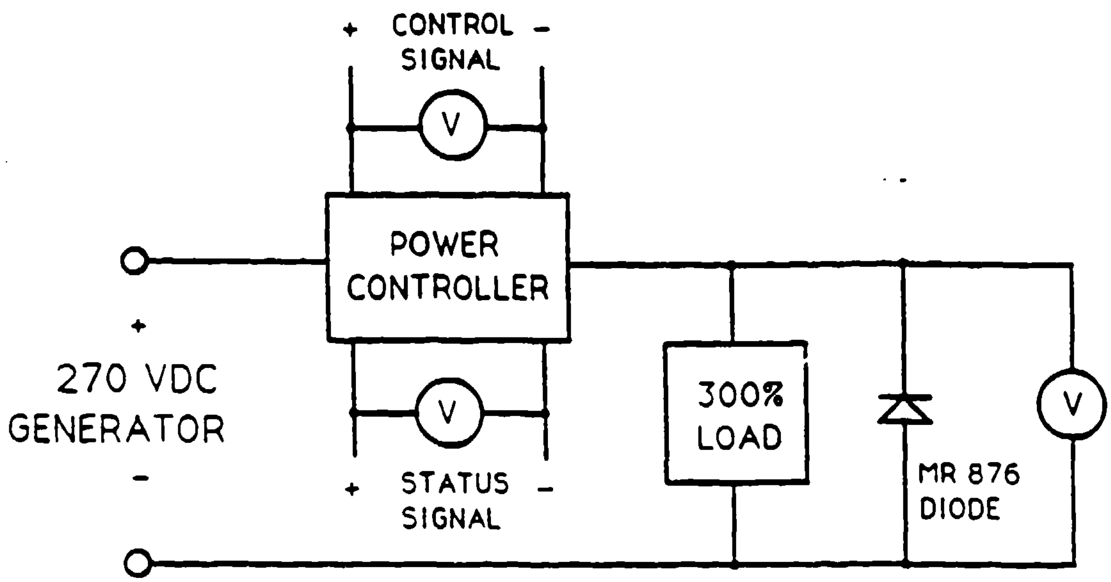
used an 8 Channel Soltec Signal Memory Recorder
to acquire transient voltage measurments

FIGURE B7 - TURN-ON AND TURN-OFF TIME FUNCTIONAL TEST CONFIGURATION



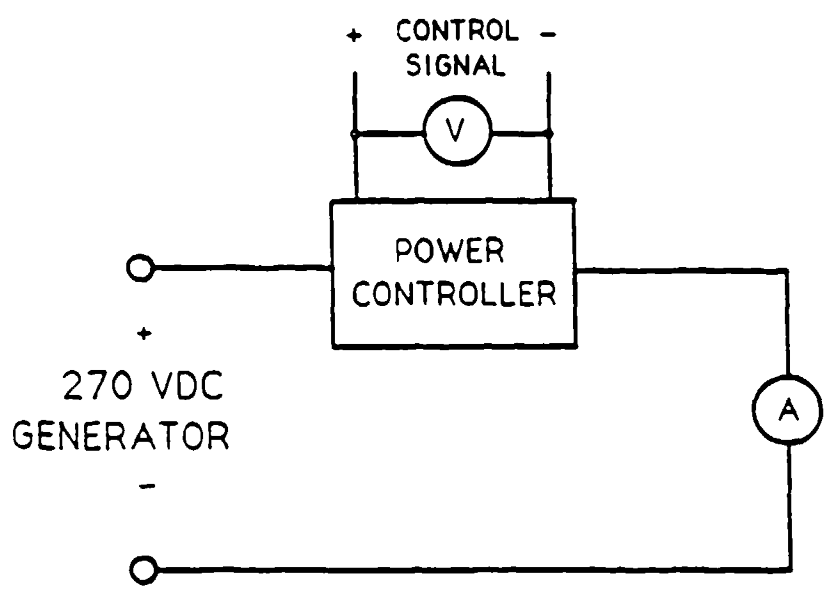
used a Fluke 8012A Digital Multimeter to acquire
the voltage drop measurments

FIGURE B8 - VOLTAGE DROP FUNCTIONAL TEST CONFIGURATION



used an 8 Channel Soltec Signal Memory Recorder
to acquire transient voltage measurments

FIGURE B9-TRIP TIME FUNCTIONAL TEST CONFIGURATION



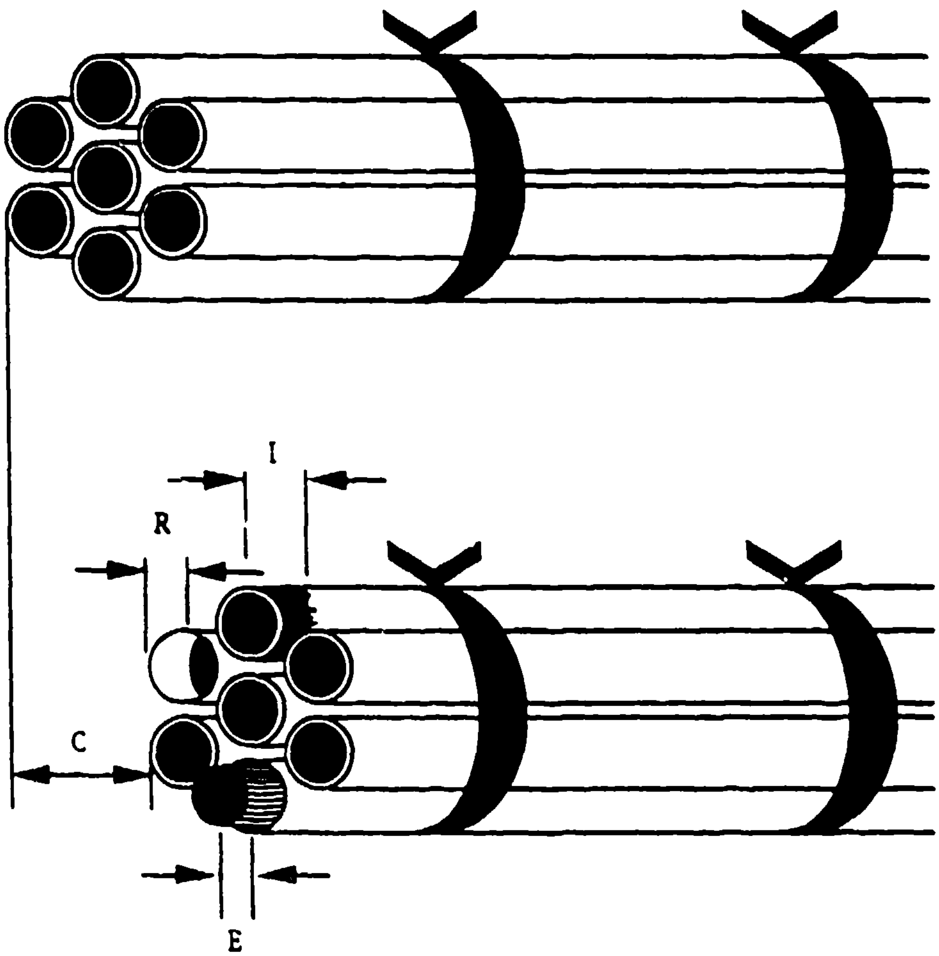
used an 8 Channel Soltec Signal Memory Recorder
to acquire transient voltage measurments

FIGURE B10-CURRENT LIMITING FUNCTIONAL TEST CONFIGURATION

APPENDIX C

TEST RESULTS OF INORGANIC INSULATIONS

Inclusive pages: 76 - 80



C - WIRE CONSUMED
I - INSULATION CHARRED
E - EXPOSED CONDUCTOR
R - RECESSED CONDUCTOR

FIGURE C1 - DESCRIPTION OF HARNESS DAMAGE MEASUREMENTS

TABLE C1 - CHAMPLAIN INORGANIC DRY ARC PROP. TEST RESULTS

Number of conductors: 7
Gauge of conductors: 20

	LENGTH OF HARNESS CONSUMED (inches)	LENGTH OF CHARRED INSULATION (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR (inches)
HARNESS #1:			
Wire #1 : -270 Vdc	6.94	0.25	-0.03
Wire #2 : +270 Vdc	6.81	0.23	-0.11
Wire #3 : -270 Vdc	6.81	0.13	-0.06
Wire #4 : +270 Vdc	6.75	0.33	-0.14
Wire #5 : -270 Vdc	7.00	0.25	-0.06
Wire #6 : +270 Vdc	6.88	0.40	-0.11
Wire #7 : -270 Vdc	6.94	0.25	-0.06
AVERAGE :	6.88	0.26	-0.08
HARNESS #2:			
Wire #1 : -270 Vdc	7.00	0.08	-0.05
Wire #2 : +270 Vdc	6.94	0.25	-0.02
Wire #3 : -270 Vdc	7.06	0.02	-0.03
Wire #4 : +270 Vdc	6.18	0.27	-0.02
Wire #5 : -270 Vdc	6.88	0.09	-0.05
Wire #6 : +270 Vdc	6.81	0.30	-0.02
Wire #7 : -270 Vdc	6.75	0.38	±0.00
AVERAGE :	6.80	0.20	-0.03
HARNESS #3:			
Wire #1 : -270 Vdc	6.38	0.41	-0.06
Wire #2 : +270 Vdc	6.44	0.33	-0.02
Wire #3 : -270 Vdc	6.38	0.16	-0.05
Wire #4 : +270 Vdc	6.25	0.33	±0.00
Wire #5 : -270 Vdc	6.50	1.06	-0.05
Wire #6 : +270 Vdc	6.13	0.53	-0.02
Wire #7 : -270 Vdc	6.75	0.23	-0.08
AVERAGE :	6.40	0.44	-0.04

TABLE C2 - THERMATICS INORGANIC DRY ARC PROP. TEST RESULTS

Number of conductors: 7
Gauge of conductors: 14

	LENGTH OF HARNESS CONSUMED (inches)	LENGTH OF CHARRED INSULATION (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR (inches)
HARNESS #1:			
Wire #1 : -270 Vdc	8.00	0.56	+0.39
Wire #2 : +270 Vdc	7.75	0.38	+0.31
Wire #3 : -270 Vdc	8.25	0.45	+0.14
Wire #4 : +270 Vdc	8.50	0.28	+0.06
Wire #5 : -270 Vdc	8.50	0.11	+0.09
Wire #6 : +270 Vdc	8.13	0.09	+0.05
Wire #7 : -270 Vdc	7.88	0.16	+0.06
AVERAGE :	8.14	0.29	+0.16
HARNESS #2:			
Wire #1 : -270 Vdc	7.25	0.30	+0.19
Wire #2 : +270 Vdc	7.63	0.31	+0.09
Wire #3 : -270 Vdc	7.94	0.08	+0.05
Wire #4 : +270 Vdc	7.94	0.16	+0.06
Wire #5 : -270 Vdc	7.44	0.13	+0.06
Wire #6 : +270 Vdc	0.81	0.11	+0.06
Wire #7 : -270 Vdc	1.00	0.00	+0.03
AVERAGE :	5.72	0.16	+0.08
HARNESS #3:			
Wire #1 : -270 Vdc	2.88	4.75	+4.25
Wire #2 : +270 Vdc	7.63	0.47	+0.11
Wire #3 : -270 Vdc	7.00	0.72	+0.50
Wire #4 : +270 Vdc	2.00	0.84	+0.08
Wire #5 : -270 Vdc	2.88	0.25	+0.06
Wire #6 : +270 Vdc	2.13	0.14	+0.03
Wire #7 : -270 Vdc	7.31	0.17	+0.06
AVERAGE :	4.55	1.05	+0.73

TABLE C3 - INDEPENDENT INORGANIC DRY ARC PROP. TEST RESULTS

Number of conductors: 6
Gauge of conductors: 12

	LENGTH OF HARNESS CONSUMED (inches)	LENGTH OF CHARRED INSULATION (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR (inches)
HARNESS #1:			
Wire #1 : -270 Vdc	1.69	0.06	+0.03
Wire #2 : +270 Vdc	1.56	0.13	+0.09
Wire #3 : -270 Vdc	1.63	0.13	+0.05
Wire #4 : +270 Vdc	1.09	0.16	+0.05
Wire #5 : -270 Vdc	1.69	0.09	+0.03
Wire #6 : +270 Vdc	1.63	0.25	+0.08
AVERAGE :	1.55	0.14	+0.06
HARNESS #2:			
Wire #1 : -270 Vdc	1.63	0.03	+0.05
Wire #2 : +270 Vdc	1.69	0.34	+0.09
Wire #3 : -270 Vdc	1.69	0.06	+0.02
Wire #4 : +270 Vdc	1.63	0.16	+0.03
Wire #5 : -270 Vdc	1.63	0.19	+0.03
Wire #6 : +270 Vdc	1.50	0.25	+0.08
AVERAGE :	1.63	0.18	+0.05
HARNESS #3:			
Wire #1 : -270 Vdc	1.10	0.09	+0.03
Wire #2 : +270 Vdc	1.31	0.19	+0.05
Wire #3 : -270 Vdc	1.10	0.09	+0.06
Wire #4 : +270 Vdc	1.25	0.17	+0.08
Wire #5 : -270 Vdc	1.31	0.16	+0.03
Wire #6 : +270 Vdc	1.19	0.19	+0.11
AVERAGE :	1.21	0.15	+0.06

TABLE C4 - INORGANIC DRY ARC PROP. PEAK CURRENT AMPLITUDE AND SHORT CIRCUIT CURRENT DURATION

TEST NO.	SPECIMEN (harness #)	PEAK VALUE IN GEN. RETURN CURRENT	TIME DURATION OF SHORT IN GEN. RETURN CURRENT
1.	Champlain #1	547 amps	5.00 seconds (*)
2.	Champlain #2	439 amps	5.03 seconds (*)
3.	Champlain #3	706 amps	5.02 seconds (*)
4.	Thermatics #1	522 amps	5.05 seconds (*)
5.	Thermatics #2	536 amps	4.60 seconds (#)
6.	Thermatics #3	479 amps	5.02 seconds (*)
7.	Independent #1	515 amps	5.03 seconds (*)
8.	Independent #2	612 amps	5.00 seconds (*)
9.	Independent #3	644 amps	5.02 seconds (*)

Notes:

(*) - Generator Control Unit removed power to extinguish the arc.

(#) - The arc was extinguished because of wire separation near the lower Bakelite collar.

APPENDIX D

PHOTOGRAPHS OF INORGANIC TEST SPECIMENS

Inclusive pages: 82 - 90

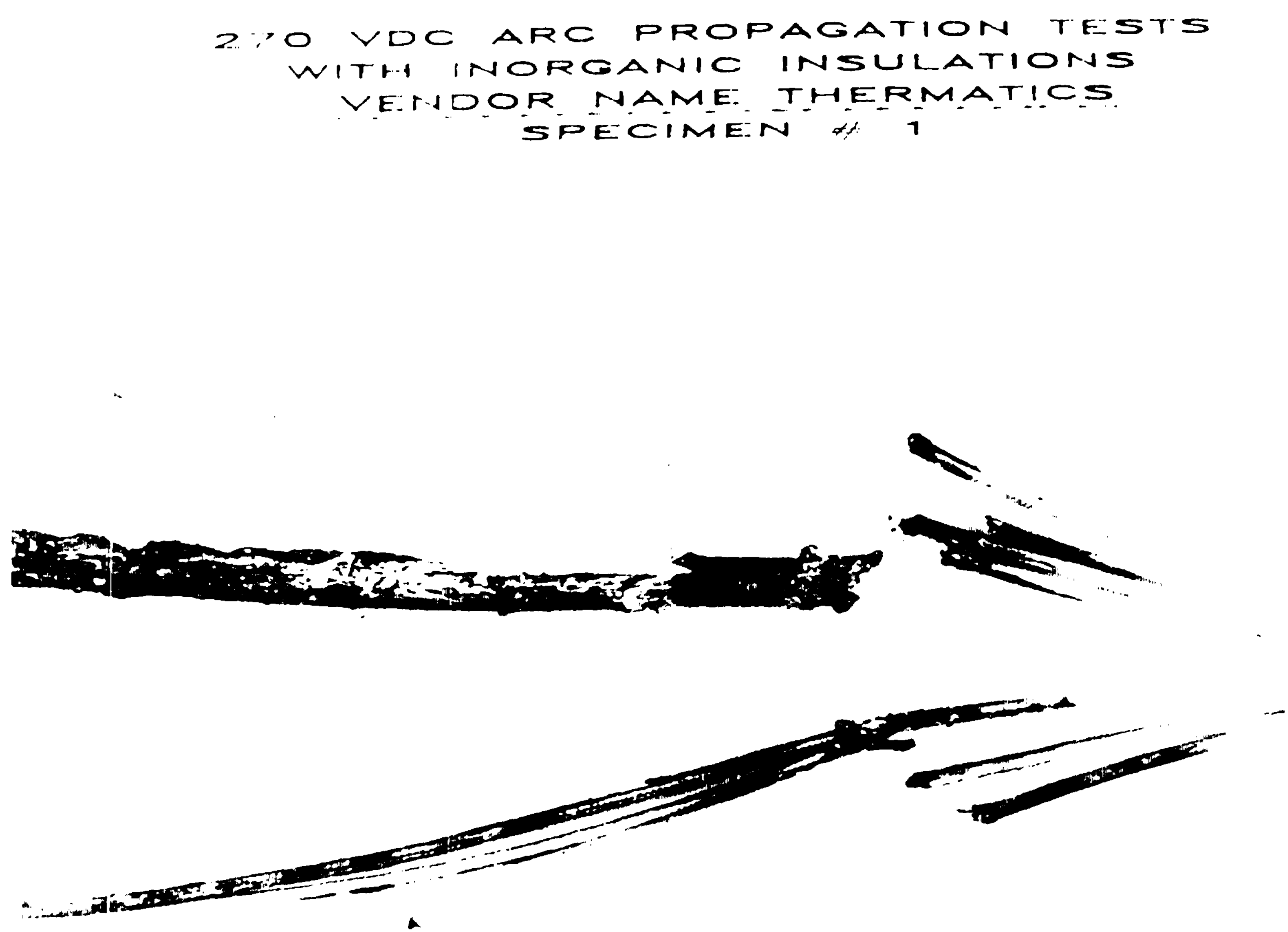


FIGURE D1 - CHAMPLAIN INORGANIC TEST SPECIMEN #1

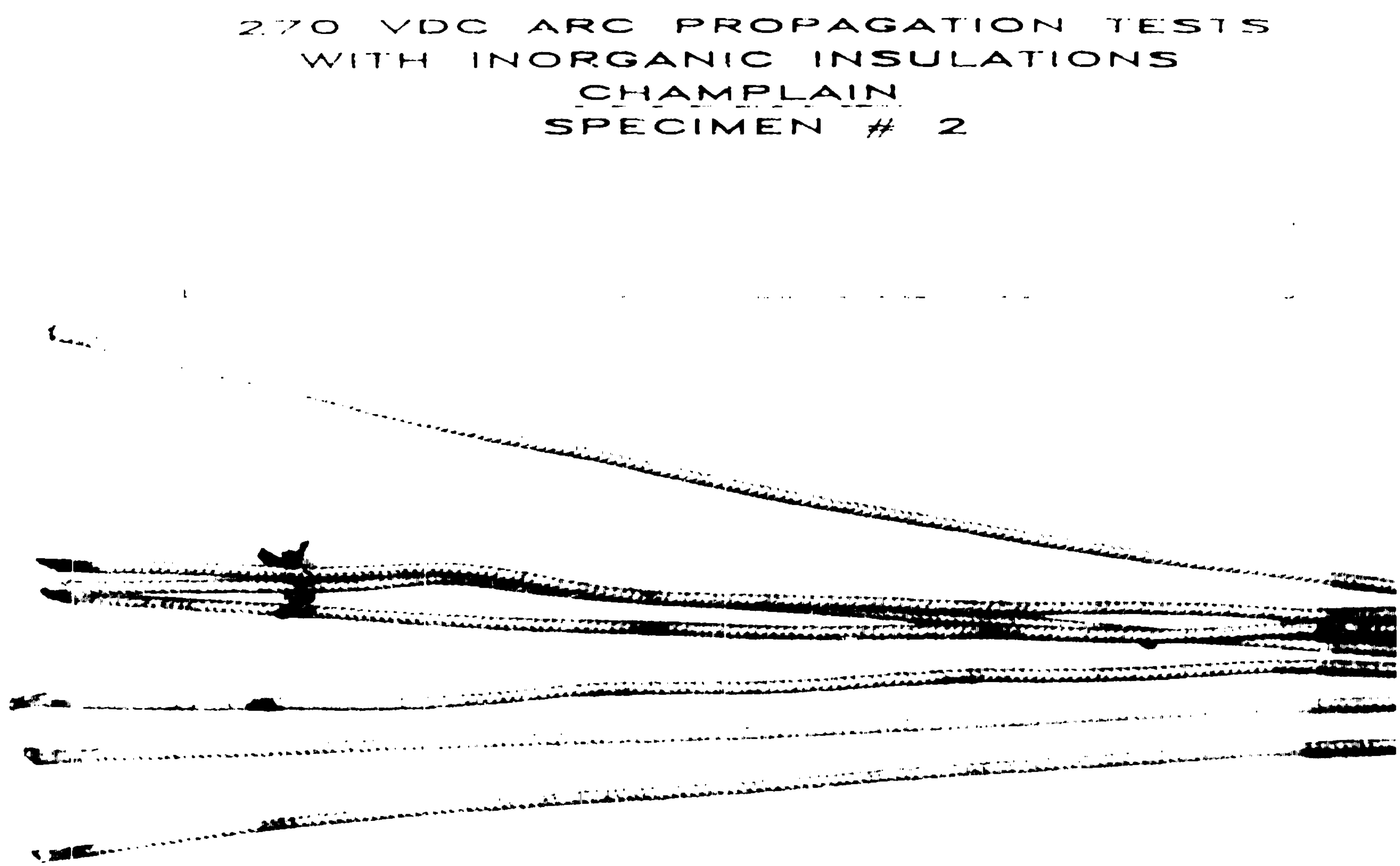


FIGURE D2 - CHAMPLAIN INORGANIC TEST SPECIMEN #2

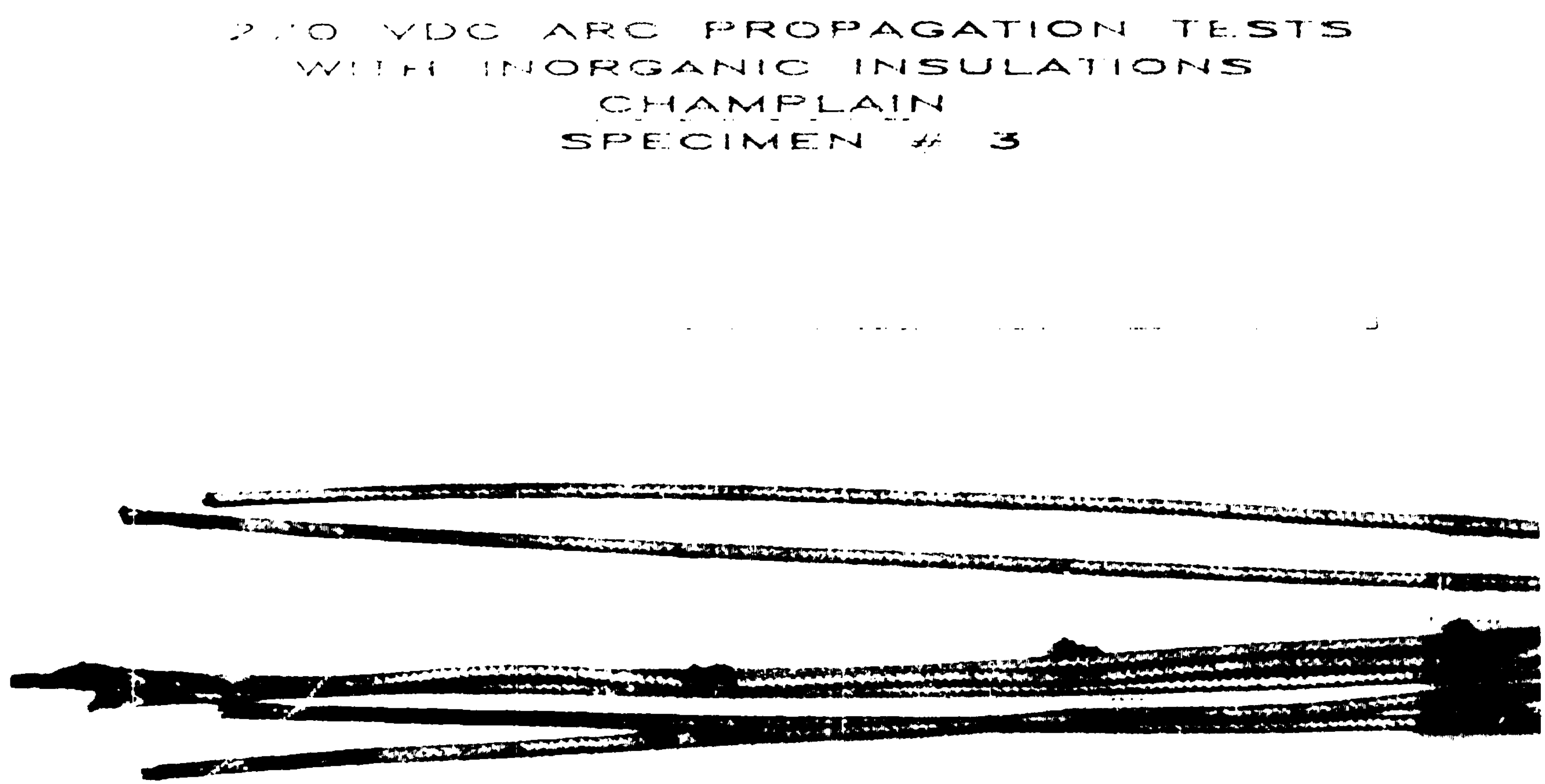


FIGURE D3 - CHAMPLAIN INORGANIC TEST SPECIMEN #3

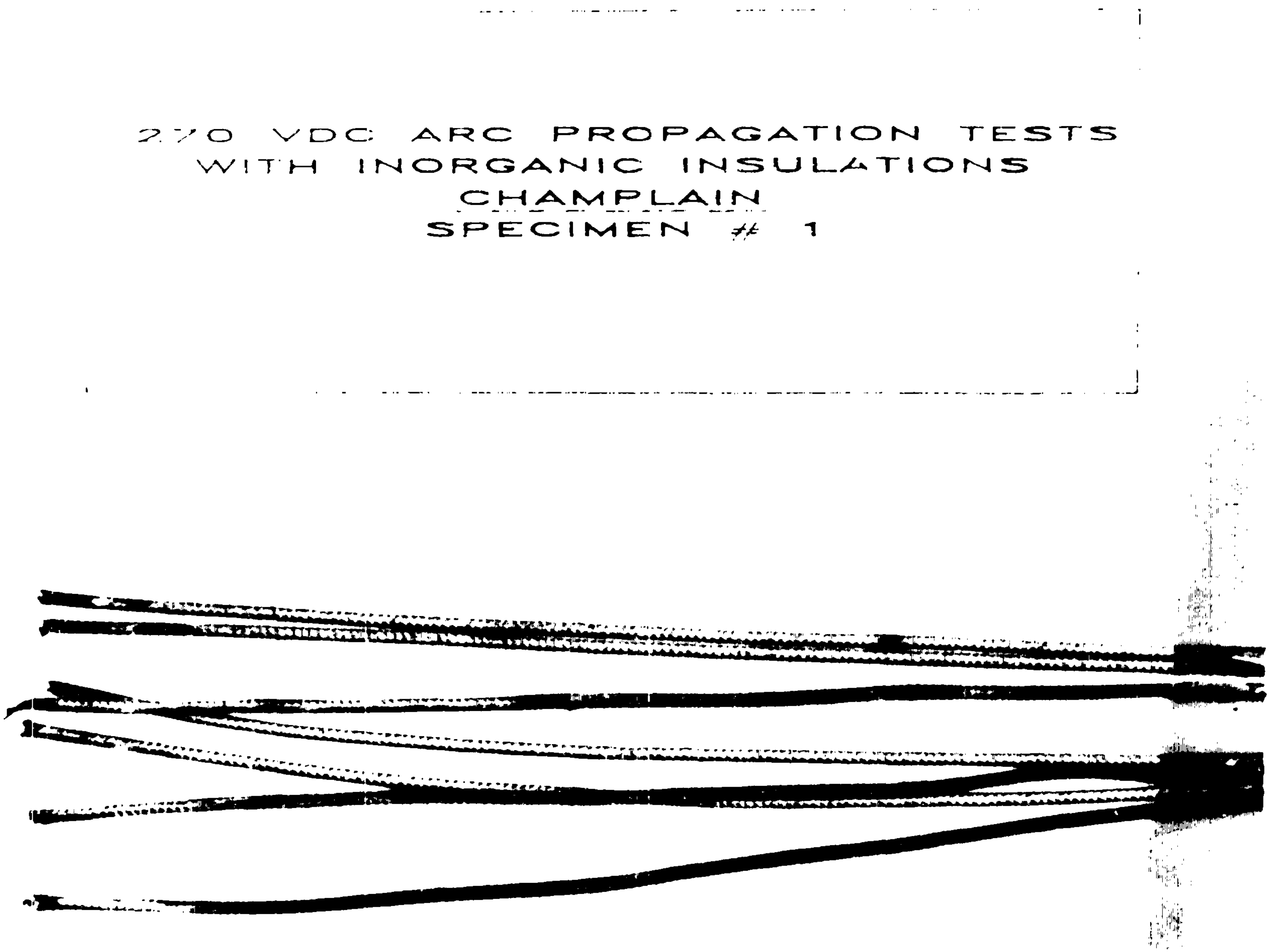


FIGURE D4 - THERMATICS INORGANIC TEST SPECIMEN #1

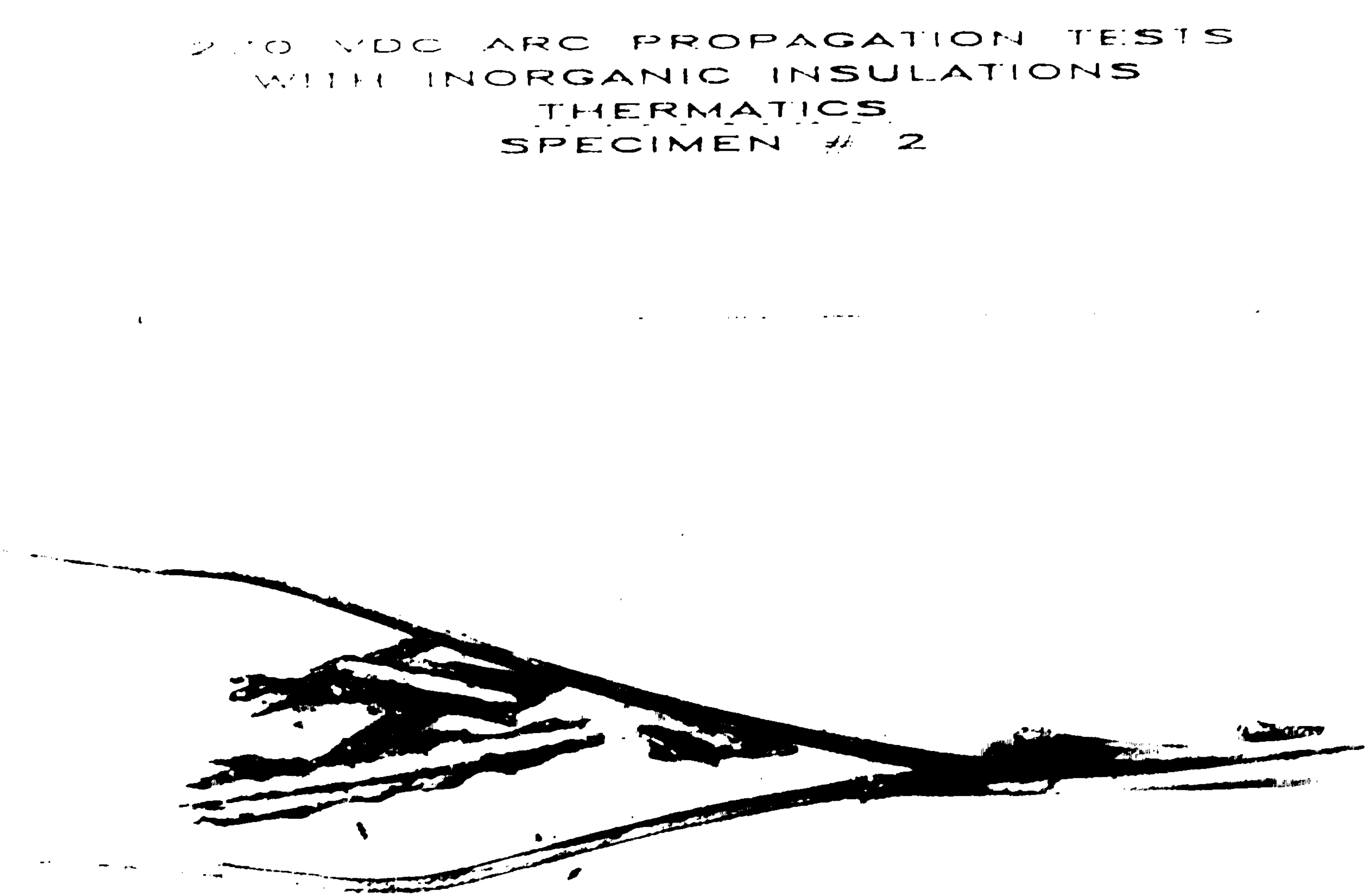


FIGURE D5 - THERMATICS INORGANIC TEST SPECIMEN #2

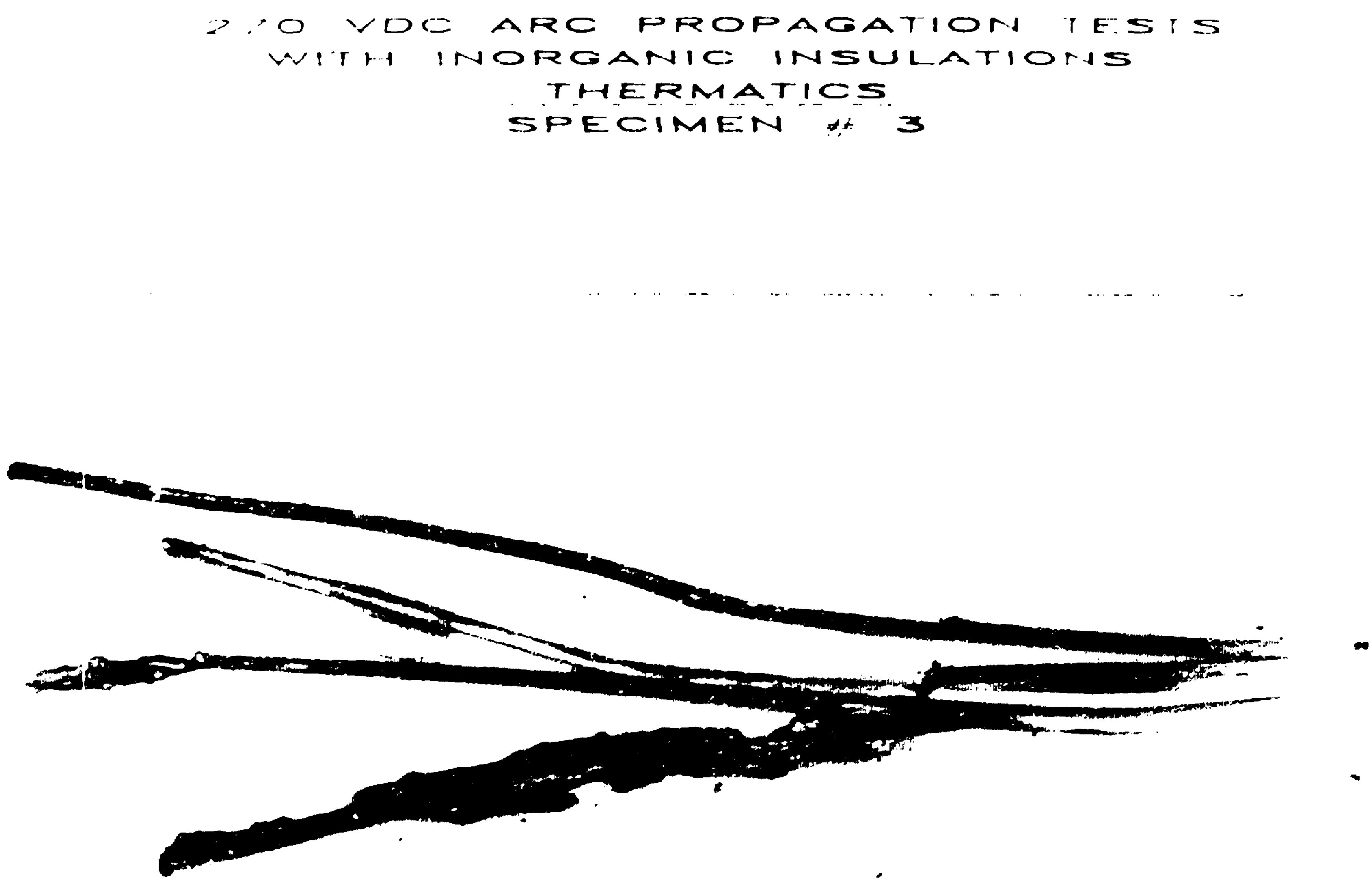


FIGURE D6 - THERMATICS INORGANIC TEST SPECIMEN #3

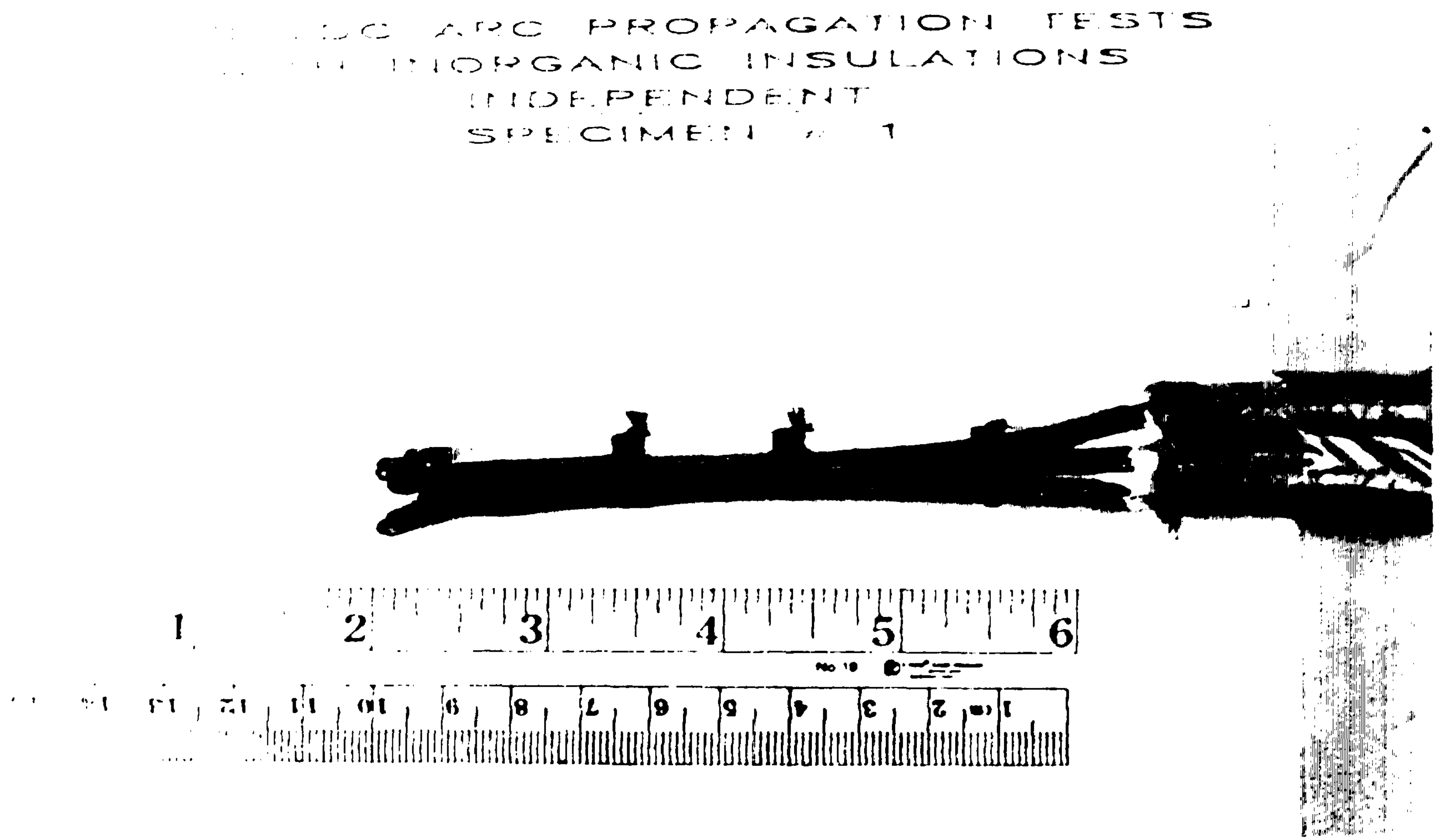


FIGURE D7 - INDEPENDENT INORGANIC TEST SPECIMEN #1

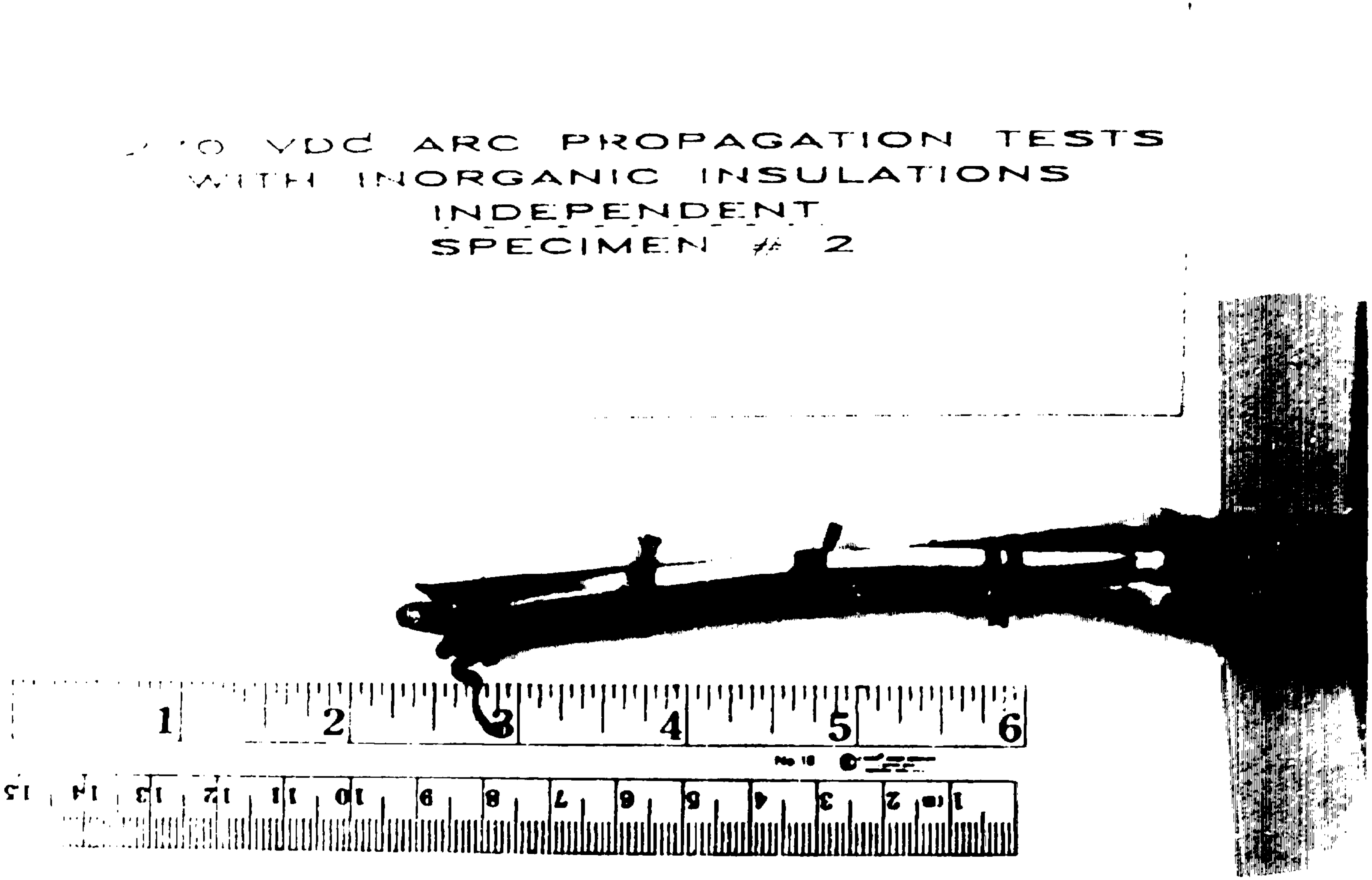


FIGURE D8 - INDEPENDENT INORGANIC TEST SPECIMEN #2

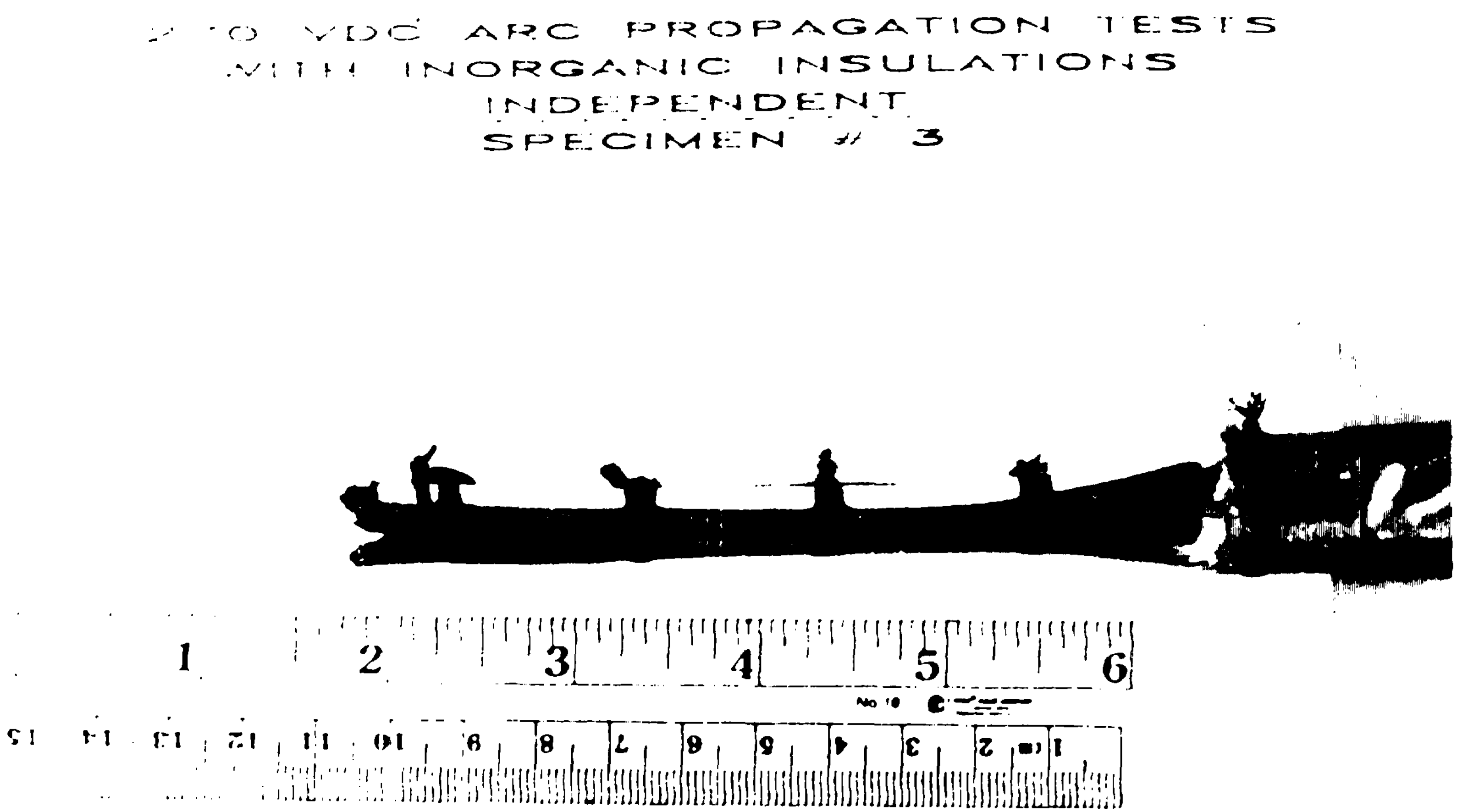


FIGURE D9 - INDEPENDENT INORGANIC TEST SPECIMEN #3

APPENDIX E

POWER CONTROLLER SCHEMATICS

Inclusive pages: 92 - 98

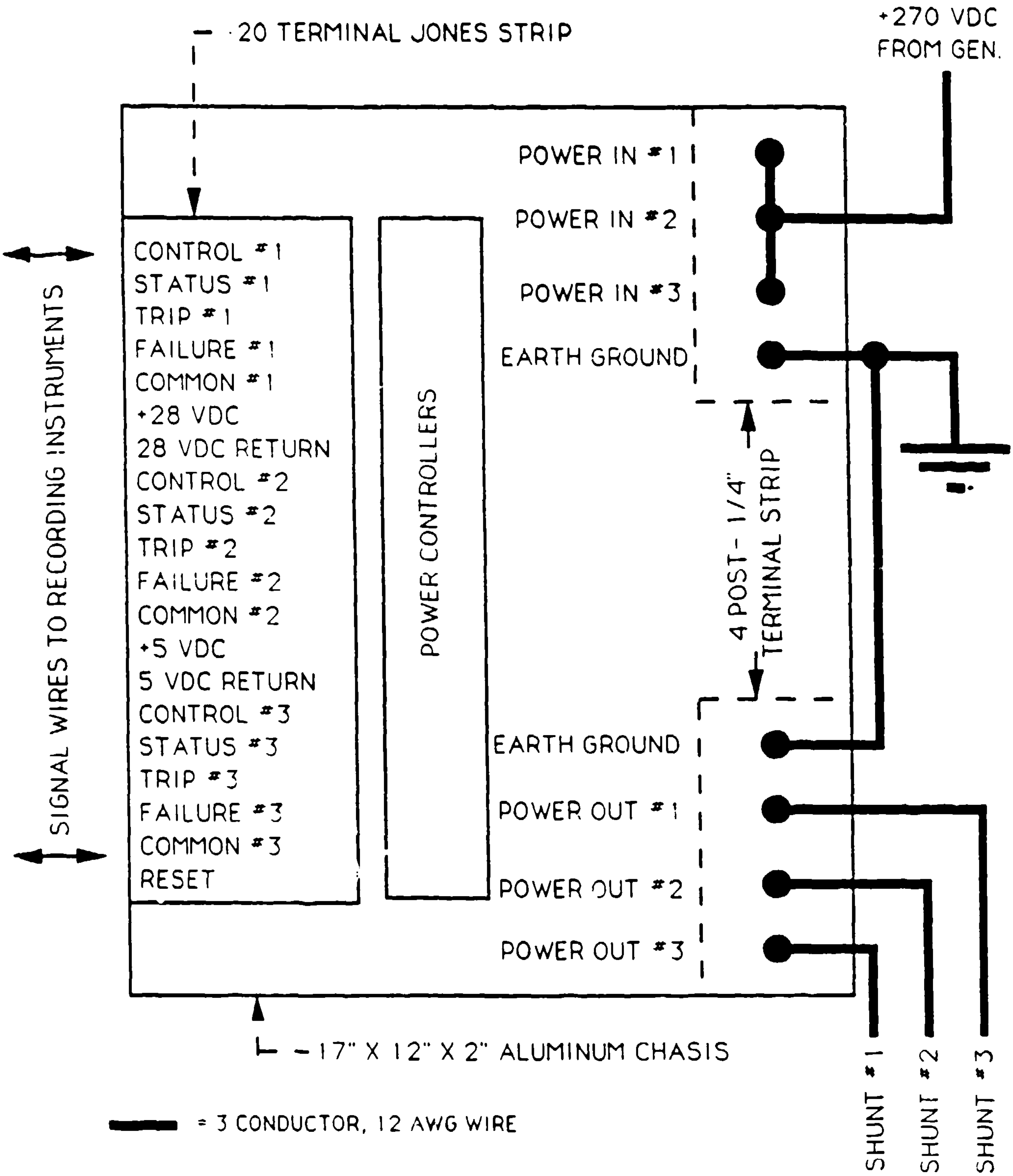


FIGURE E1-GENERAL CHASIS CONFIGURATION FOR THE POWER CONTROLLERS

TELEDYNE SOLID STATE
RATED CURRENT: 5 AMP

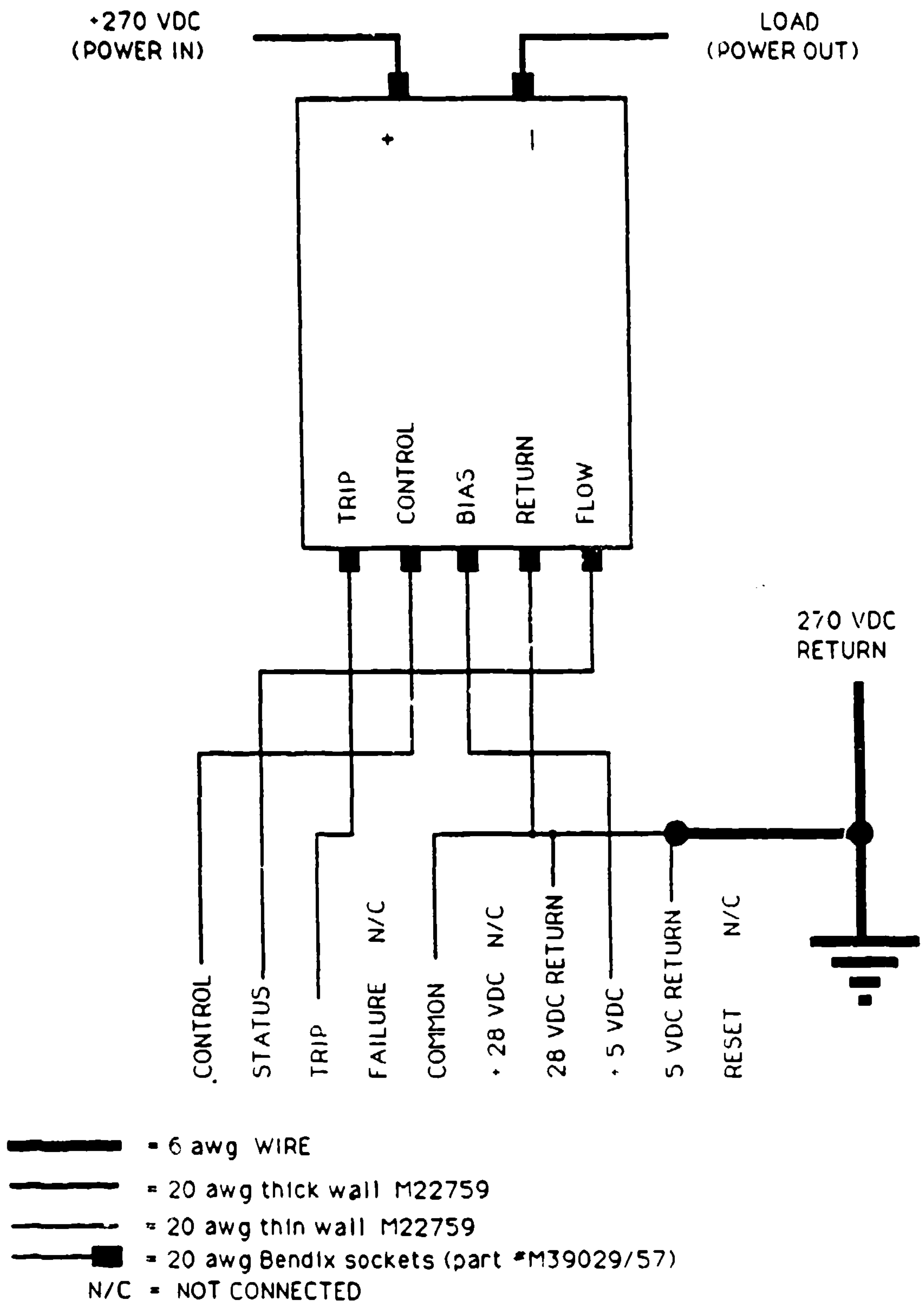


FIGURE E2-SCHEMATIC OF TELEDYNE SOLID STATE POWER CONTROLLER

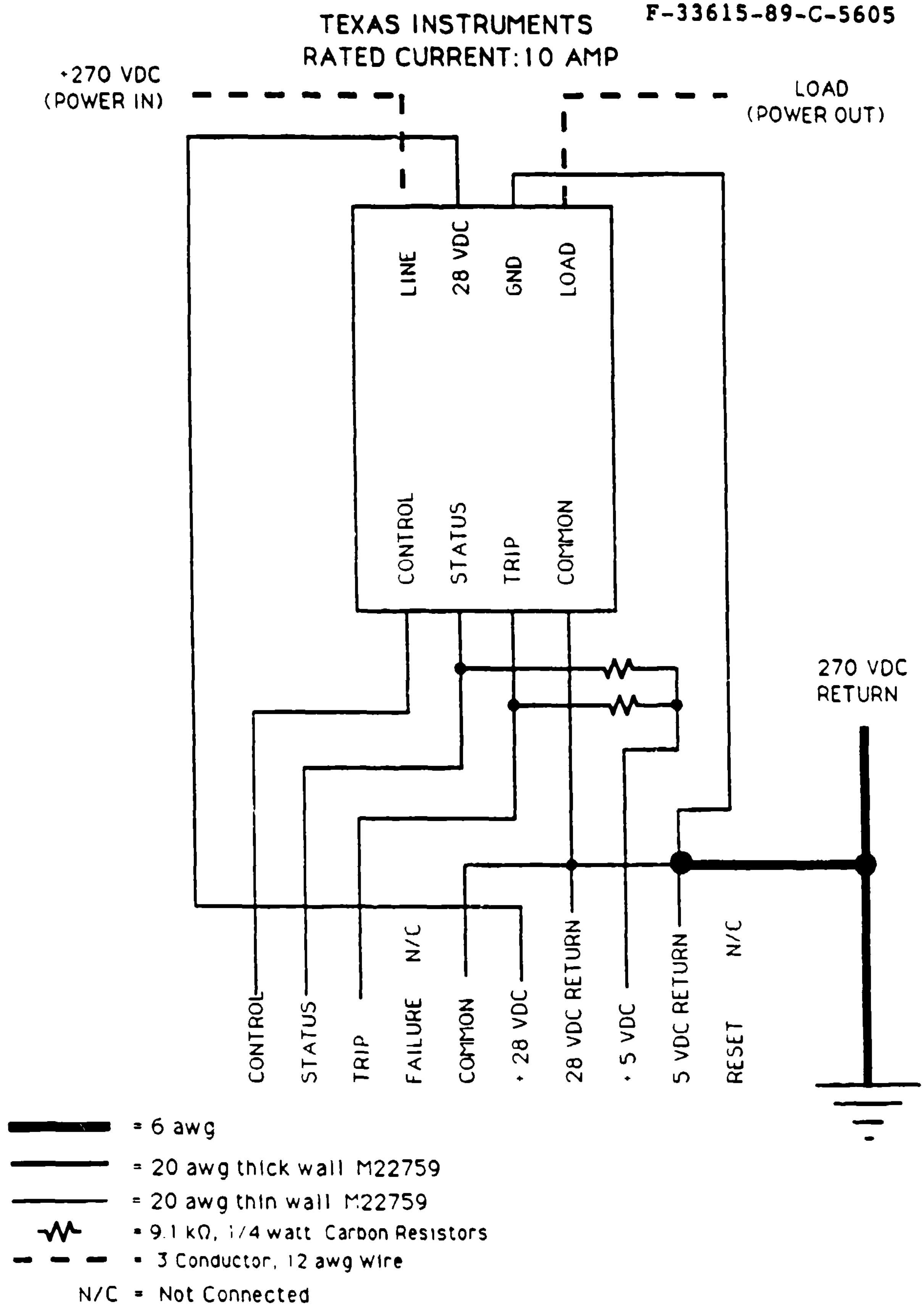
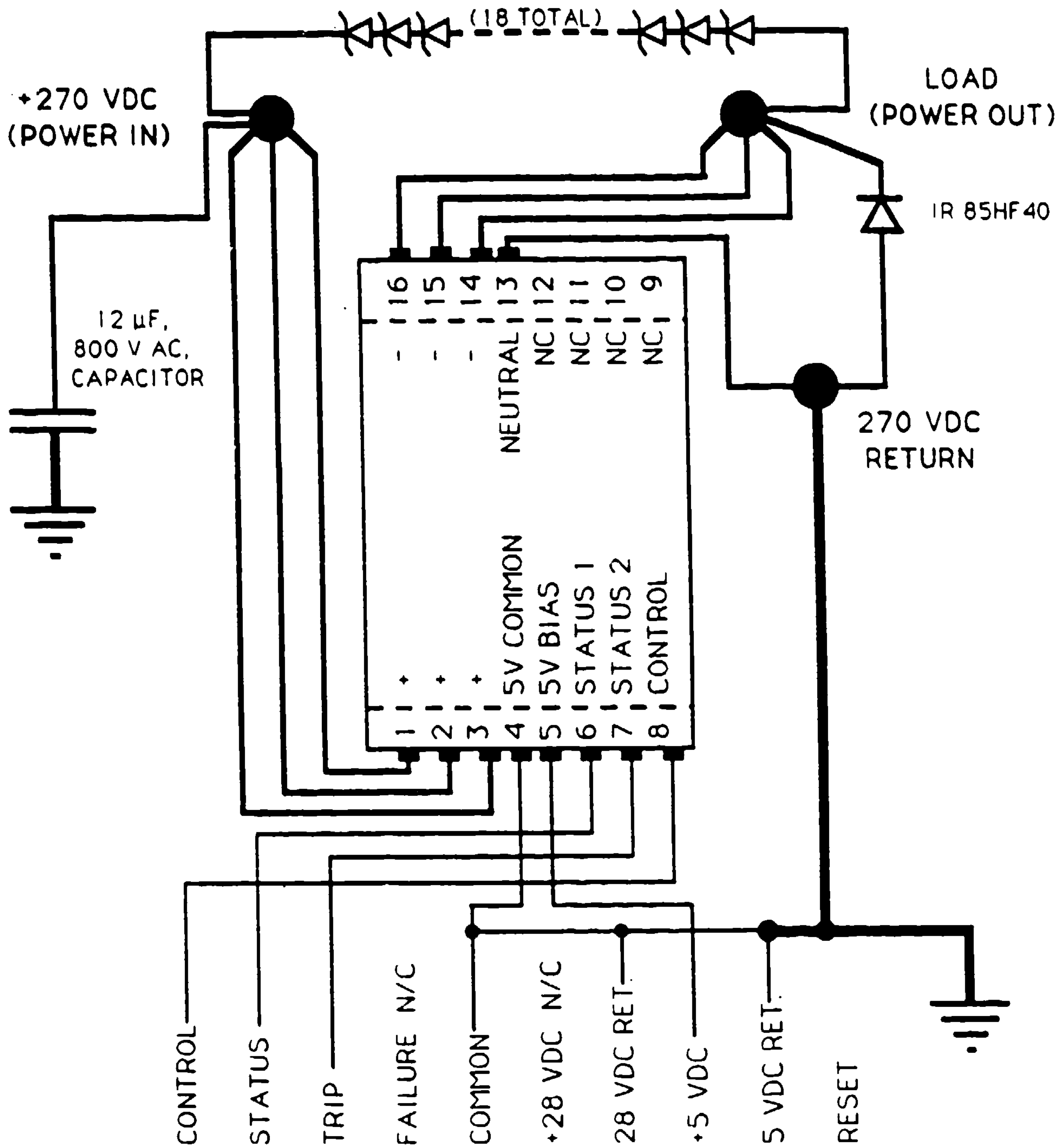


FIGURE E3 - SCHEMATIC OF TEXAS INSTRUMENTS POWER CONTROLLER

ILC DATA DEVICE CORPORATION
RATED CURRENT: 15 AMP



= 6 awg
= 20 awg thick wall M22759
= 20 awg thin wall M22759
=Transorb (part #5KP15A)
= 20 awg Bendix sockets (part #M39029/57-357)
N/C = Not Connedcted

FIGURE E4-SCHEMATIC OF ILC DATA DEVICE CORPORATION POWER CONTROLLER

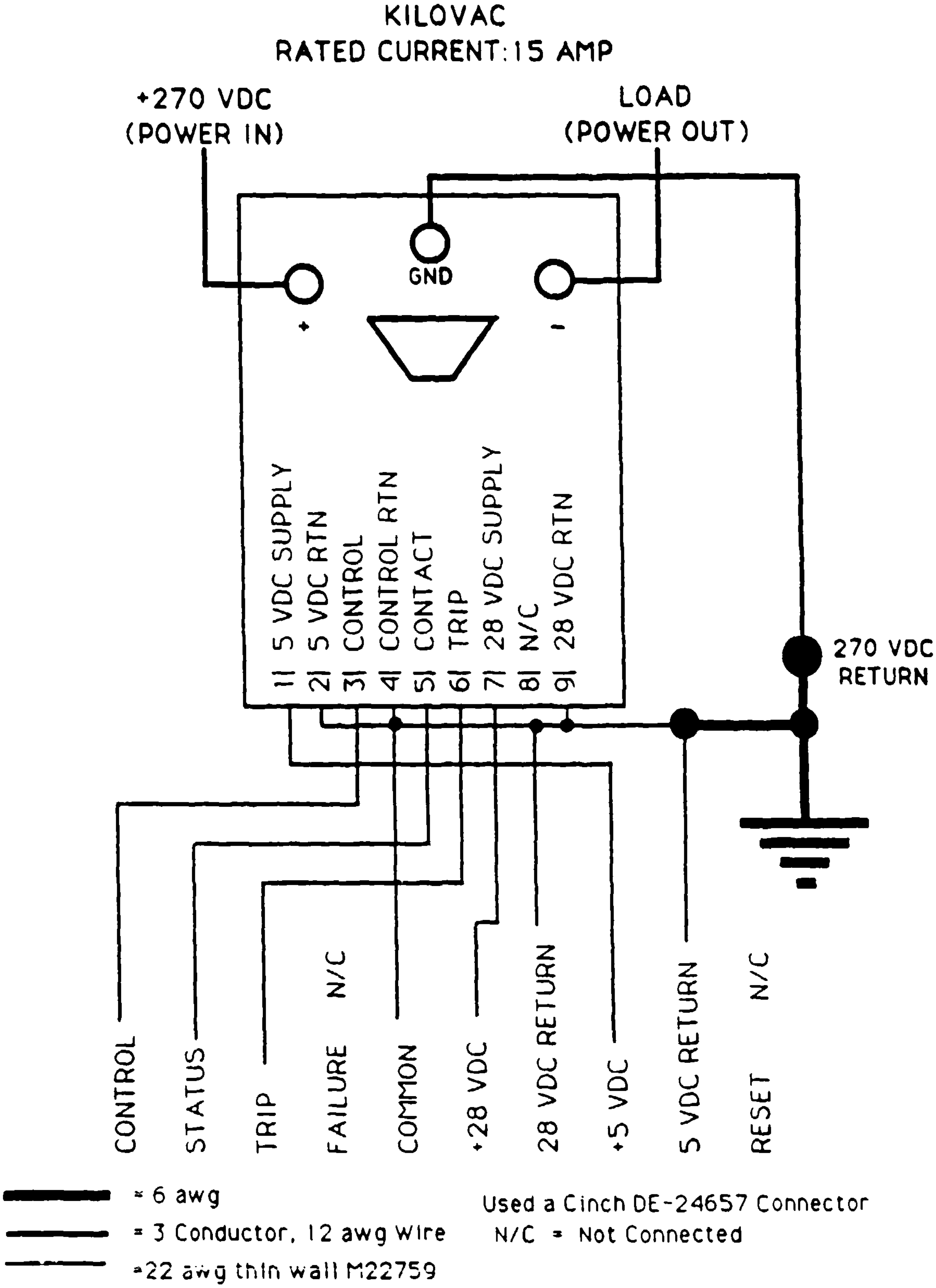
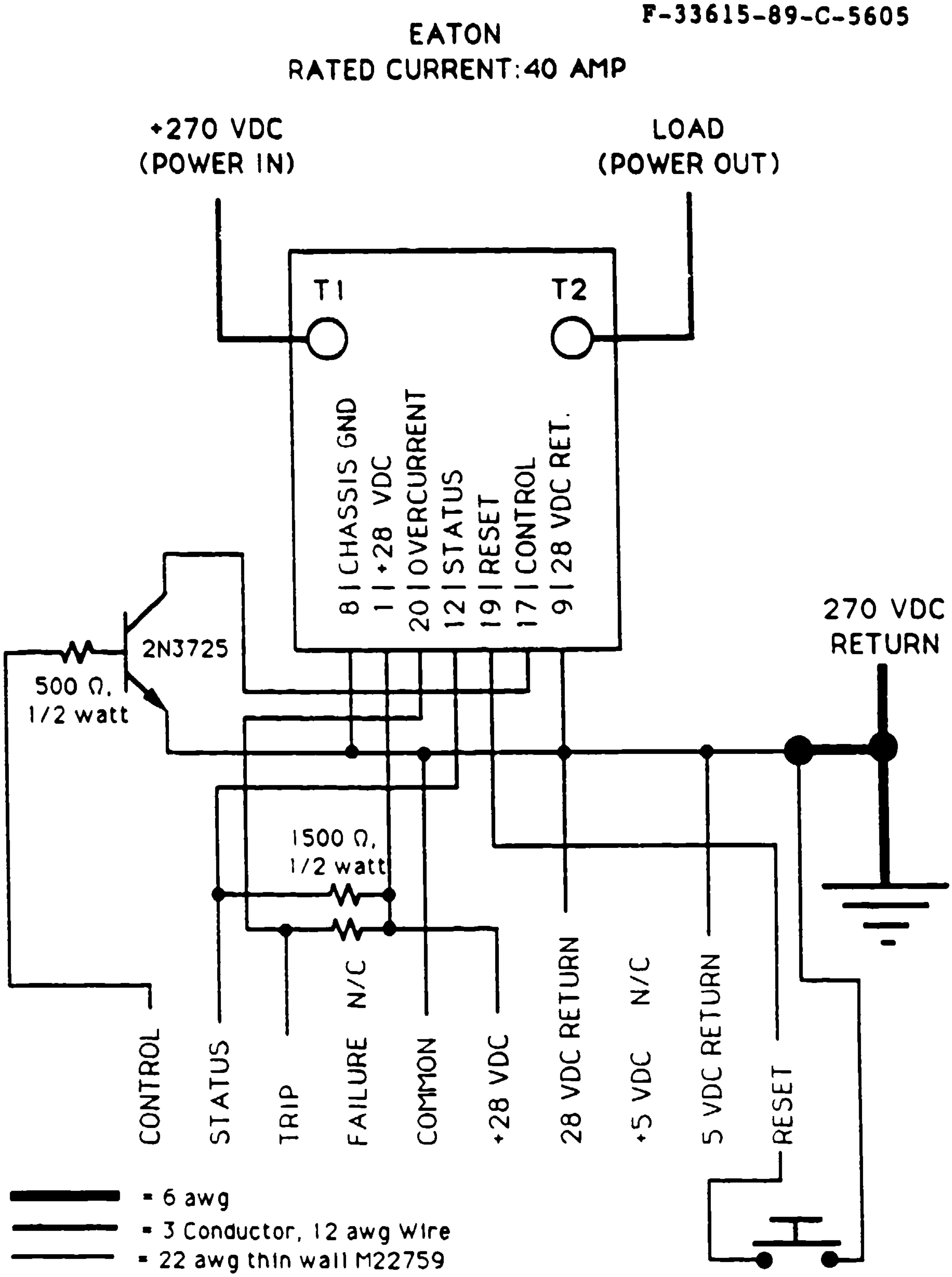


FIGURE E5 - SCHEMATIC OF KILOVAC POWER CONTROLLER



= 6 awg
= 3 Conductor, 12 awg Wire
= 22 awg thin wall M22759

Used a Bendix D38999/26WC35SN Connector

N/C = Not Connected

FIGURE E6-SCHEMATIC OF EATON POWER CONTROLLER

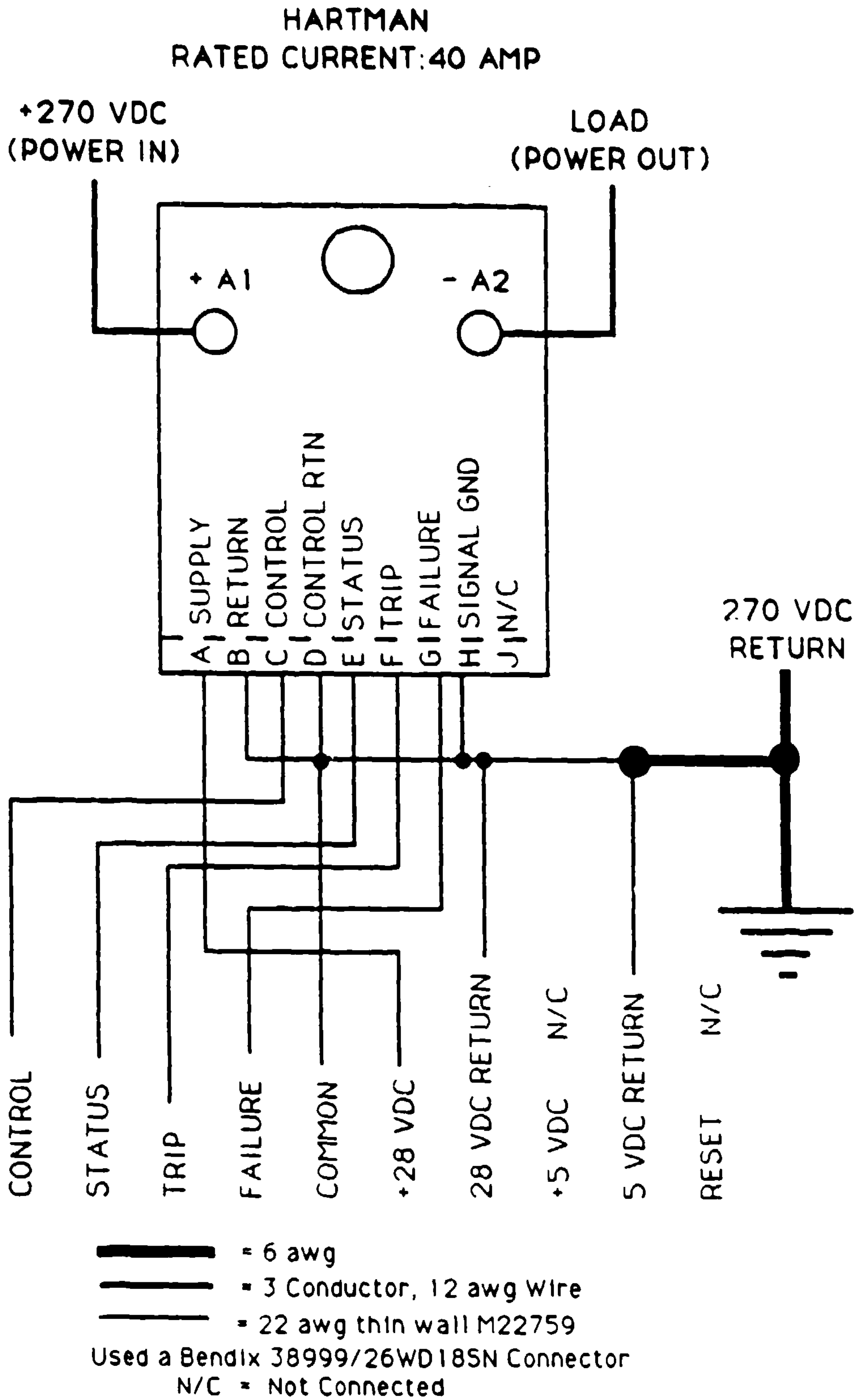


FIGURE E7-SCHEMATIC OF HARTMAN POWER CONTROLLER

APPENDIX F

PHOTOGRAPHS OF POWER CONTROLLER CHASSIS

Inclusive pages: 100 - 108

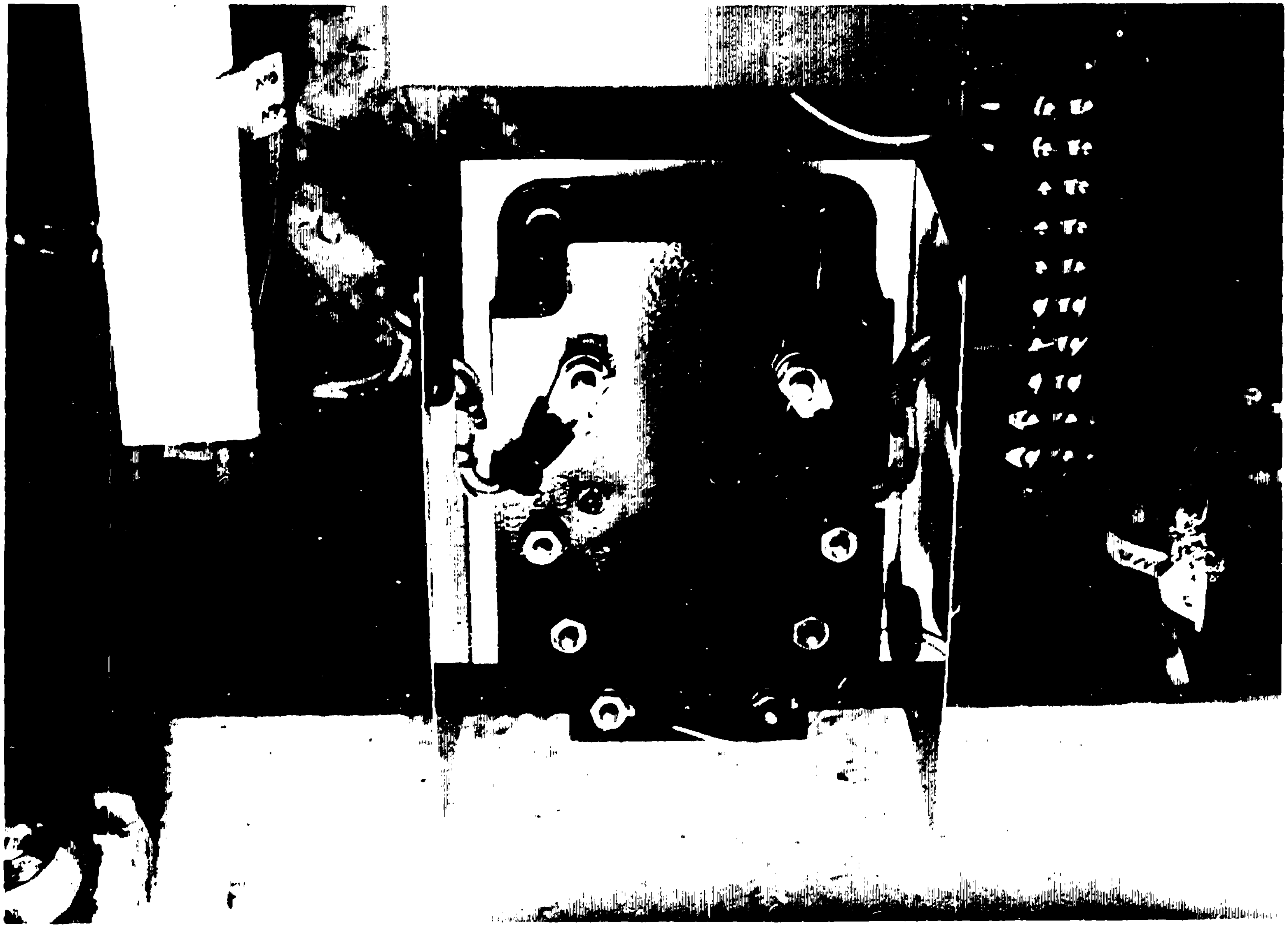


FIGURE F1 - HARTMAN MAIN LINE CONTACTOR

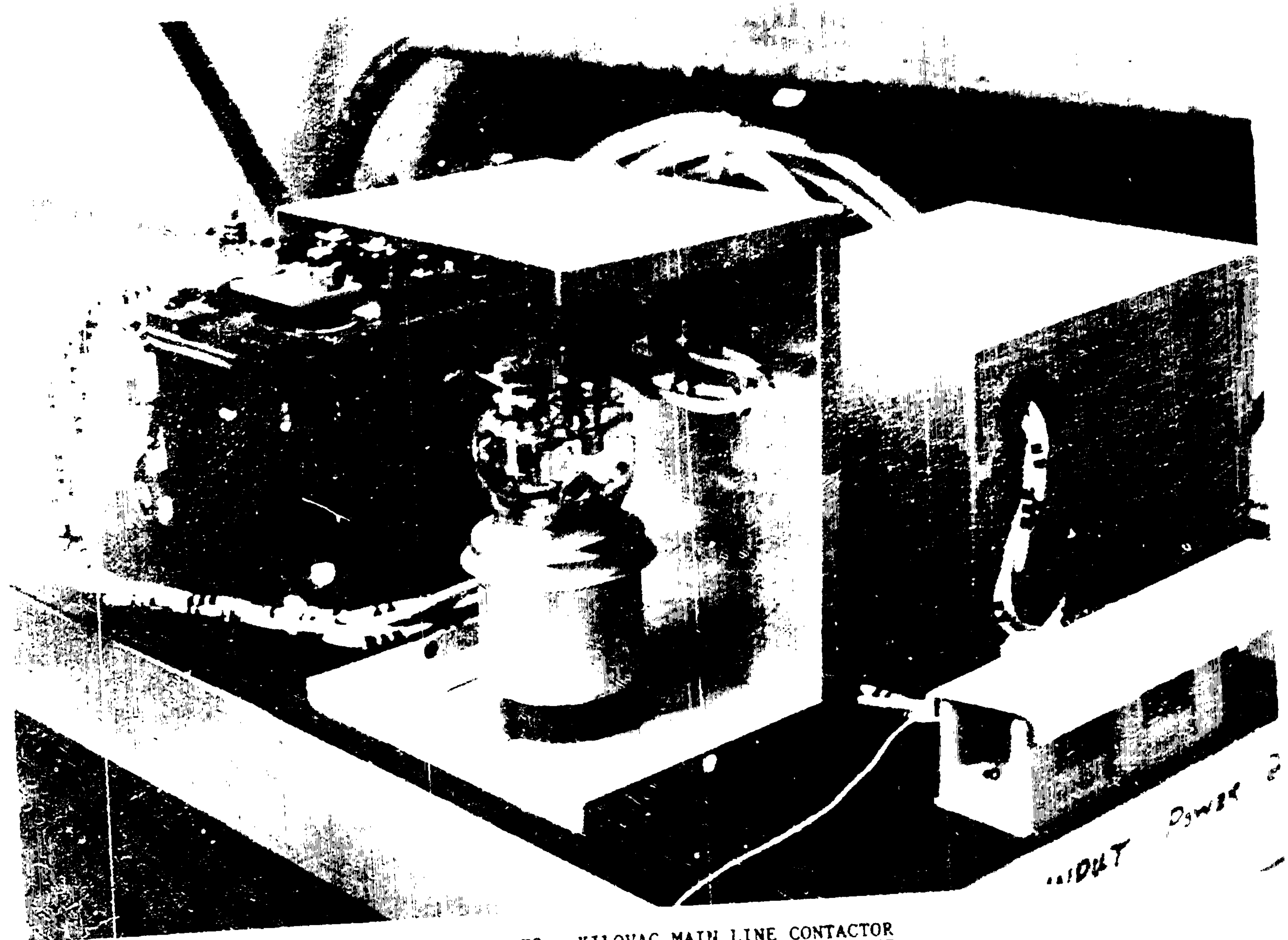


FIGURE F2 - KILOVAC MAIN LINE CONTACTOR

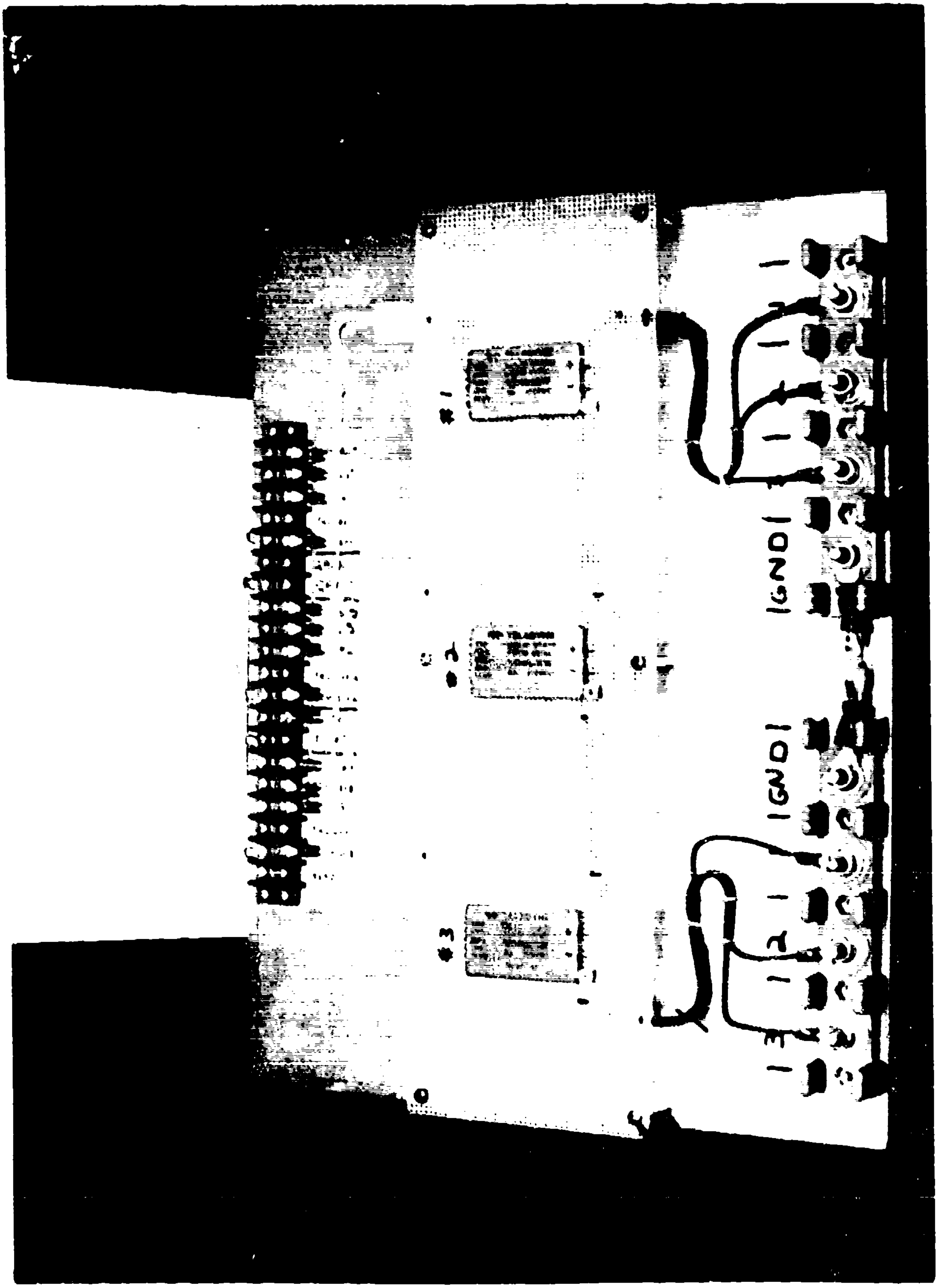


FIGURE F3 - TELEDYNE SOLID STATE POWER CONTROLLER CHASSIS

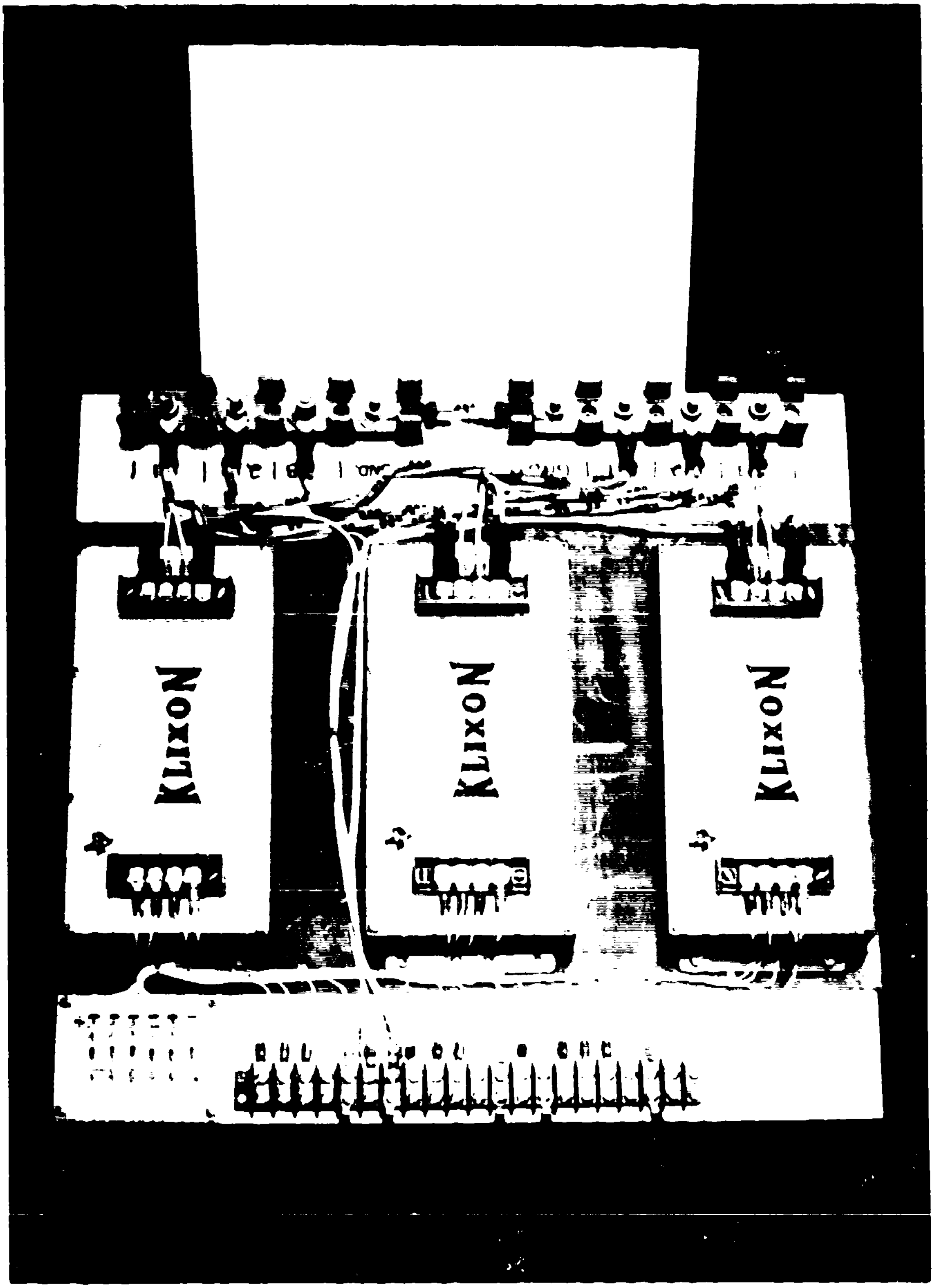


FIGURE F4- TEXAS INSTRUMENTS POWER CONTROLLER CHASSIS

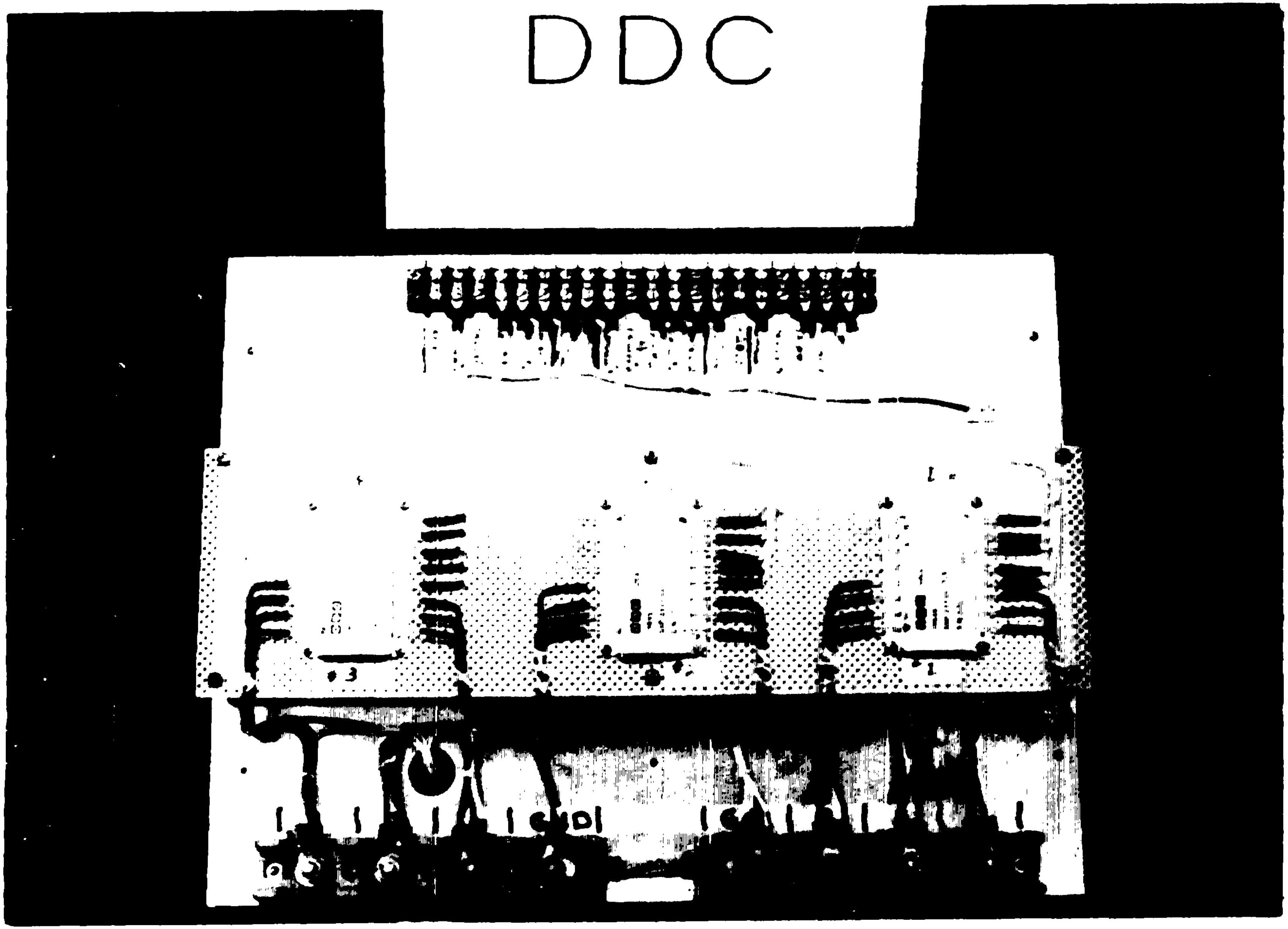
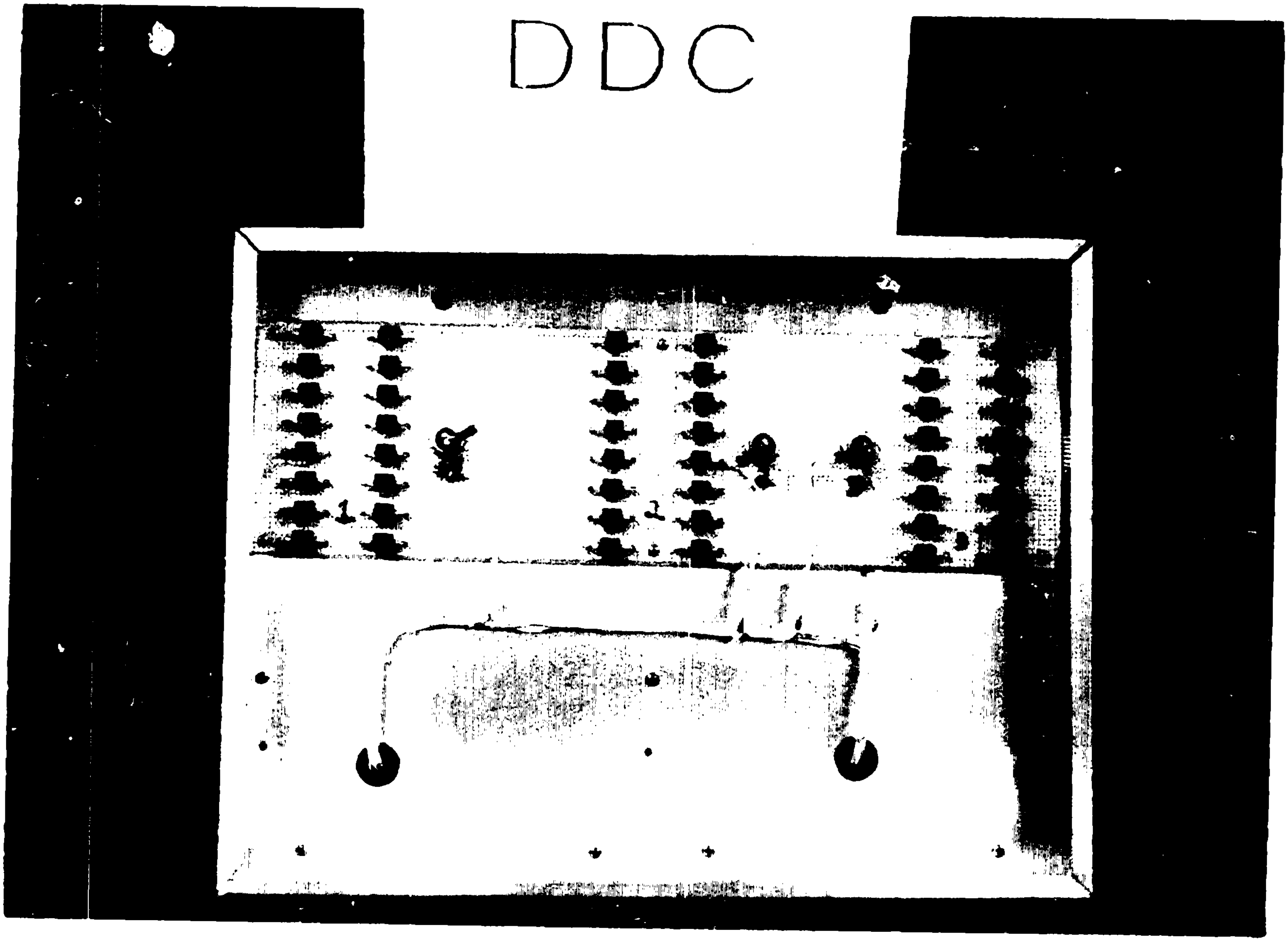


FIGURE F5 - ILC DATA DEVICE CORPORATION POWER CONTROLLER CHASSIS



FIGURF F6 - ILC DATA DEVICE CORPORATION POWER CONTROLLER CHASSIS

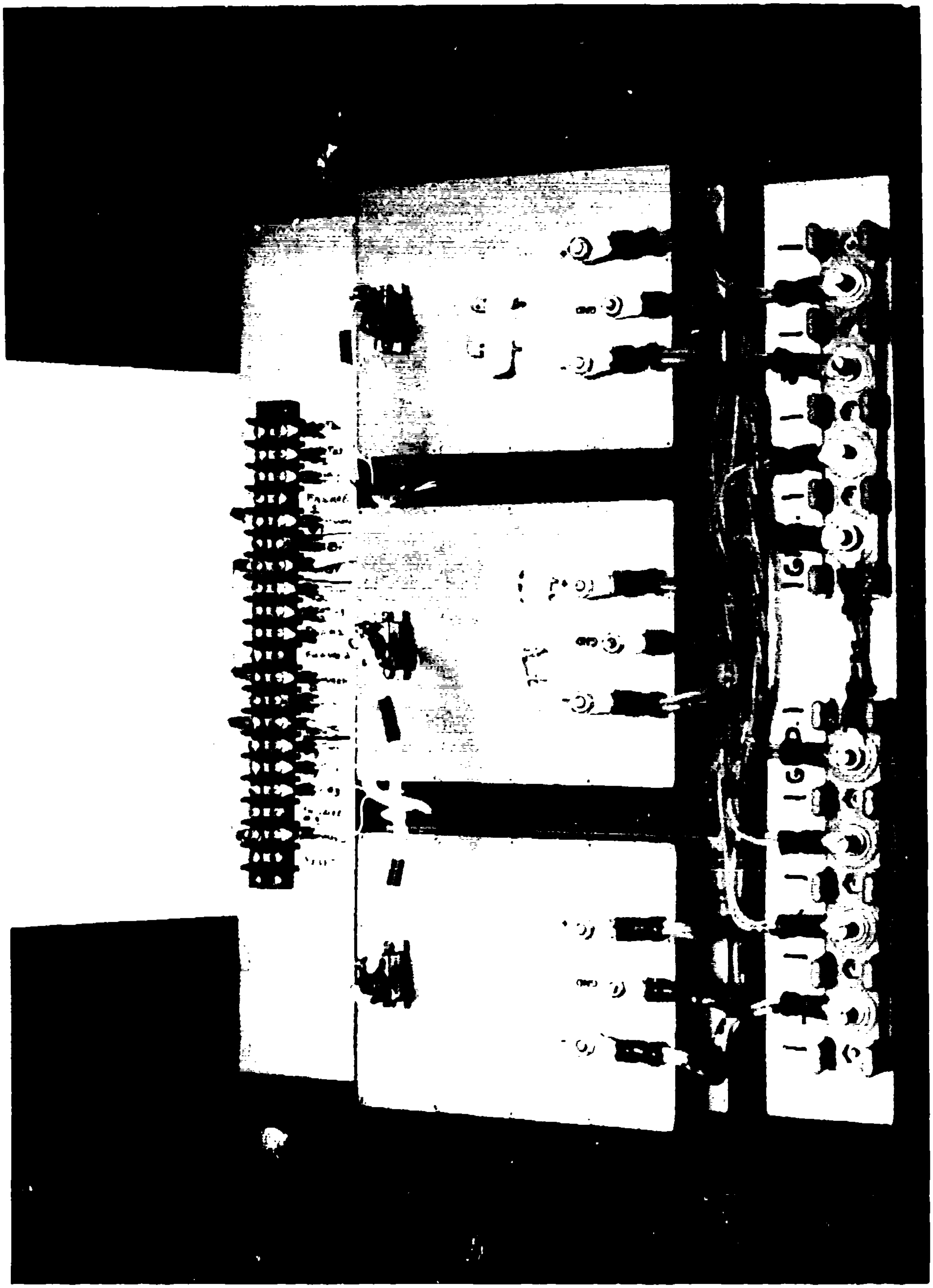


FIGURE F7 - KILOVAC POWER CONTROLLER CHASSIS

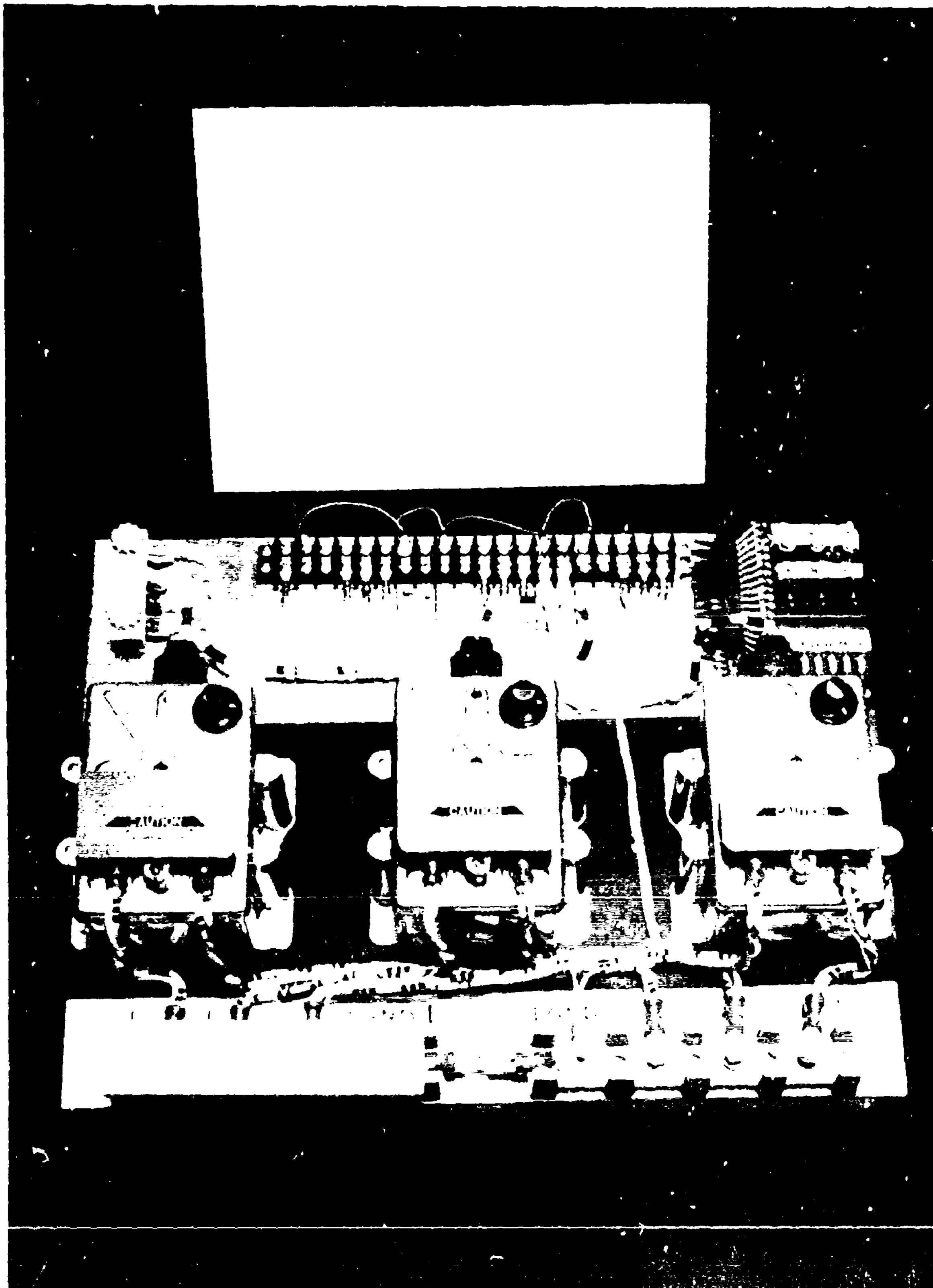


FIGURE F8 - EATON POWER CONTROLLER CHASSIS

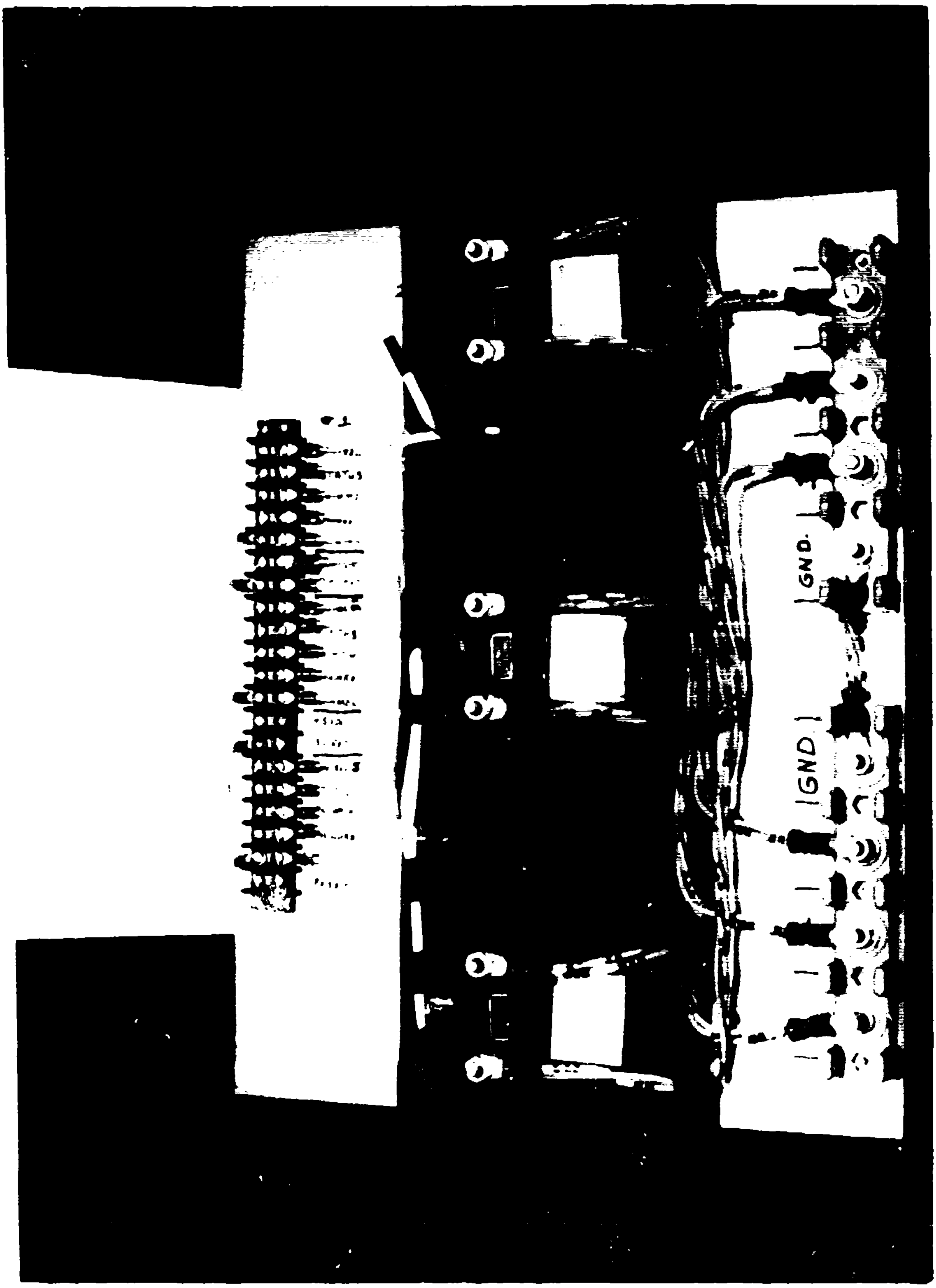


FIGURE F9 - HARTMAN POWER CONTROLLER CHASSIS

APPENDIX G

TEST RESULTS OF PROTECTED HARNESSES

Inclusive pages: 110 - 145

TABLE G1 - DRY ARC PROPAGATION TEST RESULTS FROM FILOTEX HARNESS (#237) AND TELEDYNE SOLID STATE POWER CONTROLLER

Power controller rated at 5 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.00	0.00	0.00
Wire #2 : +270 Vdc	yes	0.00	0.00	0.00
Wire #3 : -270 Vdc	yes	0.00	0.00	0.00
Wire #4 : +270 Vdc	yes	0.00	0.00	0.00
Wire #5 : -270 Vdc	yes	0.00	0.00	0.00
Wire #6 : +270 Vdc	yes	0.00	0.00	0.00
Wire #7 : -270 Vdc	yes	0.00	0.00	0.00
AVERAGE :		0.00	0.00	0.00

Notes:

There was no darkening of conductors observed on the shorting face of the harness but slight conductor strand fusing was observed.

Trip Time

Current Duration PC#1: 0.340 ms
Current Duration PC#2: 0.330 ms
Current Duration PC#3: 0.339 ms
Gen. Output Current Duration: 0.400 ms

Delay Time of Trip Signal

Delay Time PC#1: -0.200 ms
Delay Time PC#2: -0.200 ms
Delay Time PC#3: -0.200 ms

Thermal printer plots are submitted as an addendum to the report.

TABLE G2 - DRY ARC PROPAGATION TEST RESULTS FROM TENSOLITE HARNESS (#242) AND TELEDYNE SOLID STATE POWER CONTROLLER

Power controller rated at 5 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.00	0.00	0.00
Wire #2 : +270 Vdc	yes	0.00	0.00	0.00
Wire #3 : -270 Vdc	yes	0.00	0.00	0.00
Wire #4 : +270 Vdc	yes	0.00	0.00	0.00
Wire #5 : -270 Vdc	yes	0.00	0.00	0.00
Wire #6 : +270 Vdc	yes	0.00	0.00	0.00
Wire #7 : -270 Vdc	yes	0.00	0.00	0.00
AVERAGE :		0.00	0.00	0.00

Notes:

Some darkening of the conductors was observed on the shorting face of the harness with minimal conductor strand fusing.

Trip Time

Current Duration PC#1: 0.351 ms
Current Duration PC#2: 0.372 ms
Current Duration PC#3: 0.314 ms
Gen. Output Current Duration: 0.418 ms

Delay Time of Trip Signal

Delay Time PC#1: -0.322 ms
Delay Time PC#2: -0.372 ms
Delay Time PC#3: -0.315 ms

Thermal printer plots are submitted as an addendum to the report.

TABLE G3 - DRY ARC PROPAGATION TEST RESULTS FROM THERMATICS HARNESS (#247) AND TELEDYNE SOLID STATE POWER CONTROLLER

Power controller rated at 5 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.00	0.00	0.00
Wire #2 : +270 Vdc	yes	0.00	0.00	0.00
Wire #3 : -270 Vdc	yes	0.00	0.00	0.00
Wire #4 : +270 Vdc	yes	0.00	0.00	0.00
Wire #5 : -270 Vdc	yes	0.00	0.00	0.00
Wire #6 : +270 Vdc	yes	0.00	0.00	0.00
Wire #7 : -270 Vdc	yes	0.00	0.00	0.00
AVERAGE :		0.00	0.00	0.00

Notes:

There was no darkening of conductors observed on the shorting face of the harness but slight conductor strand fusing was observed.

Trip Time

Current Duration PC#1: 0.334 ms
Current Duration PC#2: 0.350 ms
Current Duration PC#3: 0.332 ms
Gen. Output Current Duration: 0.478 ms

Delay Time of Trip Signal

Delay Time PC#1: -0.218 ms
Delay Time PC#2: -0.266 ms
Delay Time PC#3: -0.214 ms

Thermal printer plots are submitted as an addendum to the report.

TABLE G4 - DRY ARC PROPAGATION TEST RESULTS FROM NEMA #3 HARNESS (#257) AND TELEDYNE SOLID STATE POWER CONTROLLER

Power controller rated at 5 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.00	0.00	0.00
Wire #2 : +270 Vdc	yes	0.00	0.00	0.00
Wire #3 : -270 Vdc	yes	0.00	0.00	0.00
Wire #4 : +270 Vdc	yes	0.00	0.00	0.00
Wire #5 : -270 Vdc	yes	0.00	0.00	0.00
Wire #6 : +270 Vdc	yes	0.00	0.00	0.00
Wire #7 : -270 Vdc	yes	0.00	0.00	0.00
AVERAGE :		0.00	0.00	0.00

Notes:

Some darkening of the conductors was observed on the shorting face of the harness with slight conductor strand fusing observed.

Trip Time

Current Duration PC#1: 0.358 ms
Current Duration PC#2: 0.360 ms
Current Duration PC#3: 0.322 ms
Gen. Output Current Duration: 0.399 ms

Delay Time of Trip Signal

Delay Time PC#1: -0.236 ms
Delay Time PC#2: -0.230 ms
Delay Time PC#3: -0.188 ms

Thermal printer plots are submitted as an addendum to the report.

TABLE G5 - DRY ARC PROPAGATION TEST RESULTS FROM M22759 HARNESS (#207) AND TELEDYNE SOLID STATE POWER CONTROLLER

Power controller rated at 5 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.00	0.00	0.00
Wire #2 : +270 Vdc	yes	0.00	0.00	0.00
Wire #3 : -270 Vdc	yes	0.00	0.00	0.00
Wire #4 : +270 Vdc	yes	0.00	0.00	0.00
Wire #5 : -270 Vdc	yes	0.00	0.00	0.00
Wire #6 : +270 Vdc	yes	0.00	0.00	0.00
Wire #7 : -270 Vdc	yes	0.00	0.00	0.00
AVERAGE :		0.00	0.00	0.00

Notes:

There was some darkening of conductors observed on the shorting face of the harness and at the edges of the insulation. Conductor strand fusing was observed.

Trip Time

Current Duration PC#1: 0.330 ms
Current Duration PC#2: 0.324 ms
Current Duration PC#3: 0.408 ms
Gen. Output Current Duration: 0.410 ms

Delay Time of Trip Signal

Delay Time PC#1: -0.206 ms
Delay Time PC#2: -0.206 ms
Delay Time PC#3: -0.278 ms

Thermal printer plots are submitted as an addendum to the report.

TABLE G6 - DRY ARC PROPAGATION TEST RESULTS FROM M81381 HARNESS (#202) AND TELEDYNE SOLID STATE POWER CONTROLLER

Power controller rated at 5 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.00	0.00	0.00
Wire #2 : +270 Vdc	yes	0.00	0.00	0.00
Wire #3 : -270 Vdc	yes	0.00	0.00	0.00
Wire #4 : +270 Vdc	yes	0.00	0.00	0.00
Wire #5 : -270 Vdc	yes	0.00	0.00	0.00
Wire #6 : +270 Vdc	yes	0.00	0.00	0.00
Wire #7 : -270 Vdc	yes	0.00	0.00	0.00
AVERAGE :		0.00	0.00	0.00

Notes:

There was some darkening of conductors observed on the shorting face of the harness and at the edges of the insulation. Also conductor strand fusing was observed.

Trip Time

Current Duration PC#1: 0.368 ms
Current Duration PC#2: 0.358 ms
Current Duration PC#3: 0.223 ms
Gen. Output Current Duration: 0.420 ms

Delay Time of Trip Signal

Delay Time PC#1: -0.248 ms
Delay Time PC#2: -0.228 ms
Delay Time PC#3: -0.108 ms

Thermal printer plots are submitted as an addendum to the report.

TABLE G7 - DRY ARC PROPAGATION TEST RESULTS FROM FILOTEX HARNESS (#237) AND TEXAS INSTRUMENTS POWER CONTROLLER

Power controller rated at 10 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.00	0.00	0.00
Wire #2 : +270 Vdc	yes	0.00	0.00	0.00
Wire #3 : -270 Vdc	yes	0.00	0.00	0.00
Wire #4 : +270 Vdc	yes	0.00	0.00	0.00
Wire #5 : -270 Vdc	yes	0.00	0.00	0.00
Wire #6 : +270 Vdc	yes	0.00	0.00	0.00
Wire #7 : -270 Vdc	yes	0.00	0.00	0.00
AVERAGE :		0.00	0.00	0.00

Notes:

There was darkening of conductors observed on the shorting face of the harness with conductor strand fusing present.

Trip Time

Current Duration PC#1: 0.808 ms
Current Duration PC#2: 0.800 ms
Current Duration PC#3: 0.800 ms
Gen. Output Current Duration: 0.832 ms

Delay Time of Trip Signal

Delay Time PC#1: +4.000 ms
Delay Time PC#2: +4.100 ms
Delay Time PC#3: +4.200 ms

Thermal printer plots are submitted as an addendum to the report.

TABLE G8 - DRY ARC PROPAGATION TEST RESULTS FROM TENSOLITE HARNESS (#242) AND TEXAS INSTRUMENTS POWER CONTROLLER

Power controller rated at 10 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.00	0.00	0.00
Wire #2 : +270 Vdc	yes	0.00	0.00	0.00
Wire #3 : -270 Vdc	yes	0.00	0.00	0.00
Wire #4 : +270 Vdc	yes	0.00	0.00	0.00
Wire #5 : -270 Vdc	yes	0.00	0.00	0.00
Wire #6 : +270 Vdc	yes	0.00	0.00	0.00
Wire #7 : -270 Vdc	yes	0.00	0.00	0.00
AVERAGE :		0.00	0.00	0.00

Notes:

There was darkening of conductors observed on the shorting face of the harness with conductor strand fusing present.

Trip Time

Current Duration PC#1: 0.688 ms
Current Duration PC#2: 0.688 ms
Current Duration PC#3: 0.680 ms
Gen. Output Current Duration: 0.826 ms

Delay Time of Trip Signal

Delay Time PC#1: +4.208 ms
Delay Time PC#2: +4.128 ms
Delay Time PC#3: +4.128 ms

Thermal printer plots are submitted as an addendum to the report.

TABLE G9 - DRY ARC PROPAGATION TEST RESULTS FROM THERMATICS HARNESS (#247) AND TEXAS INSTRUMENTS POWER CONTROLLER

Power controller rated at 10 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.00	0.00	0.00
Wire #2 : +270 Vdc	yes	0.00	0.00	0.00
Wire #3 : -270 Vdc	yes	0.00	0.00	0.00
Wire #4 : +270 Vdc	yes	0.00	0.00	0.00
Wire #5 : -270 Vdc	yes	0.00	0.00	0.00
Wire #6 : +270 Vdc	yes	0.00	0.00	0.00
Wire #7 : -270 Vdc	yes	0.00	0.00	0.00
AVERAGE :		0.00	0.00	0.00

Notes:

There was no darkening of conductors observed on the shorting face of the harness but a minimal amount of conductor strand fusing was present.

Trip Time

Current Duration PC#1: 0.840 ms
Current Duration PC#2: 0.740 ms
Current Duration PC#3: 0.768 ms
Gen. Output Current Duration: 0.988 ms

Delay Time of Trip Signal

Delay Time PC#1: +4.408 ms
Delay Time PC#2: +4.032 ms
Delay Time PC#3: +4.064 ms

Thermal printer plots are submitted as an addendum to the report.

TABLE G10 - DRY ARC PROPAGATION TEST RESULTS FROM NEMA #3 HARNESS (#257) AND TEXAS INSTRUMENTS POWER CONTROLLER

Power controller rated at 10 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.00	0.00	0.00
Wire #2 : +270 Vdc	yes	0.00	0.00	0.00
Wire #3 : -270 Vdc	yes	0.00	0.00	0.00
Wire #4 : +270 Vdc	yes	0.00	0.00	0.00
Wire #5 : -270 Vdc	yes	0.00	0.00	0.00
Wire #6 : +270 Vdc	yes	0.00	0.00	0.00
Wire #7 : -270 Vdc	yes	0.00	0.00	0.00
AVERAGE :		0.00	0.00	0.00

Notes:

Slight darkening of conductors was observed on the shorting face of the harness in addition to conductor strand fusing.

Trip Time

Current Duration PC#1: 0.834 ms
Current Duration PC#2: 0.824 ms
Current Duration PC#3: 0.860 ms
Gen. Output Current Duration: 0.986 ms

Delay Time of Trip Signal

Delay Time PC#1: +4.167 ms
Delay Time PC#2: +4.096 ms
Delay Time PC#3: +4.128 ms

Thermal printer plots are submitted as an addendum to the report.

TABLE G11 - DRY ARC PROPAGATION TEST RESULTS FROM M22759 HARNESS (#207) AND TEXAS INSTRUMENTS POWER CONTROLLER

Power controller rated at 10 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.00	0.00	0.00
Wire #2 : +270 Vdc	yes	0.00	0.00	0.00
Wire #3 : -270 Vdc	yes	0.00	0.00	0.00
Wire #4 : +270 Vdc	yes	0.00	0.00	0.00
Wire #5 : -270 Vdc	yes	0.00	0.00	0.00
Wire #6 : +270 Vdc	yes	0.00	0.00	0.00
Wire #7 : -270 Vdc	yes	0.00	0.00	0.00
AVERAGE :		0.00	0.00	0.00

Notes:

There was some darkening of conductors was observed on the shorting face of the harness and at the edges of the insulation. Slight conductor strand fusing was also present.

Trip Time

Current Duration PC#1: 0.672 ms
Current Duration PC#2: 0.726 ms
Current Duration PC#3: 0.666 ms
Gen. Output Current Duration: 0.806 ms

Delay Time of Trip Signal

Delay Time PC#1: +4.272 ms
Delay Time PC#2: +4.192 ms
Delay Time PC#3: +4.224 ms

Thermal printer plots are submitted as an addendum to the report.

TABLE G12 - DRY ARC PROPAGATION TEST RESULTS FROM M81381 HARNESS (#202) AND TEXAS INSTRUMENTS POWER CONTROLLER

Power controller rated at 10 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.00	0.00	0.00
Wire #2 : +270 Vdc	yes	0.00	0.00	0.00
Wire #3 : -270 Vdc	yes	0.00	0.00	0.00
Wire #4 : +270 Vdc	yes	0.00	0.00	0.00
Wire #5 : -270 Vdc	yes	0.00	0.00	0.00
Wire #6 : +270 Vdc	yes	0.00	0.00	0.00
Wire #7 : -270 Vdc	yes	0.00	0.00	0.00
AVERAGE :		0.00	0.00	0.00

Notes:

There was darkening of conductors observed on the shorting face of the harness and at the edges of the insulation. Conductor strand fusing was also present.

Trip Time

Current Duration PC#1: 1.036 ms
Current Duration PC#2: 1.220 ms
Current Duration PC#3: 1.044 ms
Gen. Output Current Duration: 1.228 ms

Delay Time of Trip Signal

Delay Time PC#1: +4.224 ms
Delay Time PC#2: +4.160 ms
Delay Time PC#3: +4.160 ms

Thermal printer plots are submitted as an addendum to the report.

TABLE G13 - ARC PROPAGATION TEST RESULTS FROM FILOTEX HARNESS (#237) AND ILC DATA DEVICE CORPORATION POWER CONTROLLER

Power controller rated at 15 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.00	0.00	0.00
Wire #2 : +270 Vdc	yes	0.00	0.00	0.00
Wire #3 : -270 Vdc	yes	0.00	0.00	0.00
Wire #4 : +270 Vdc	yes	0.00	0.00	0.00
Wire #5 : -270 Vdc	yes	0.00	0.00	0.00
Wire #6 : +270 Vdc	yes	0.00	0.00	+0.02
Wire #7 : -270 Vdc	yes	0.00	0.00	0.00
AVERAGE :		0.00	0.00	0.00

Notes:

There was slight darkening of the conductors observed on the shorting face of the harness and no visible conductor strand fusing observed.

Trip Time

Current Duration PC#1: 11.920 ms
Current Duration PC#2: 11.800 ms
Current Duration PC#3: 12.544 ms
Gen. Output Current Duration: 12.544 ms

Delay Time of Trip Signal

Delay Time PC#1: - DNA
Delay Time PC#2: - DNA
Delay Time PC#3: - DNA

DNA = Data not acquired because the status signals were not functioning properly.

Thermal printer plots are submitted as an addendum to the report.

TABLE G14 - DRY ARC PROPAGATION TEST RESULTS FROM TENSOLITE HARNESS (#242) AND ILC DATA DEVICE CORPORATION POWER CONTROLLER

Power controller rated at 15 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.00	0.00	+0.02
Wire #2 : +270 Vdc	yes	0.00	0.00	0.00
Wire #3 : -270 Vdc	yes	0.00	0.00	+0.02
Wire #4 : +270 Vdc	yes	0.00	0.00	+0.02
Wire #5 : -270 Vdc	yes	0.00	0.00	+0.02
Wire #6 : +270 Vdc	yes	0.00	0.00	0.00
Wire #7 : -270 Vdc	yes	0.00	0.00	0.00
AVERAGE :		0.00	0.00	+0.01

Notes:

Slight darkening of conductors was observed on the shorting face of the harness with conductor strand fusing present.

Trip Time

Current Duration PC#1: 3.700 ms
Current Duration PC#2: 3.200 ms
Current Duration PC#3: 3.660 ms
Gen. Output Current Duration: 3.832 ms

Delay Time of Trip Signal

Delay Time PC#1: - DNA
Delay Time PC#2: - DNA
Delay Time PC#3: - DNA

DNA = Data not acquired because the status signals were not functioning properly.

Thermal printer plots are submitted as an addendum to the report.

TABLE G15 - DRY ARC PROPAGATION TEST RESULTS FROM THERMATICS HARNESS (#247) AND ILC DATA DEVICE CORPORATION POWER CONTROLLER

Power controller rated at 15 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.13	0.28	-0.02
Wire #2 : +270 Vdc	yes	0.13	0.27	+0.02
Wire #3 : -270 Vdc	yes	0.00	0.33	+0.02
Wire #4 : +270 Vdc	yes	0.00	0.25	-0.03
Wire #5 : -270 Vdc	yes	0.00	0.27	-0.02
Wire #6 : +270 Vdc	yes	0.13	0.25	-0.03
Wire #7 : -270 Vdc	yes	0.13	0.30	-0.02
AVERAGE :		0.07	0.28	-0.01

Notes:

An average of 0.28 inches of a black carbon residue and charring was observed at the shorting end of the harness. Conductor strand fusing was present.

Trip Time

Current Duration PC#1: 36.30 ms
Current Duration PC#2: 36.30 ms
Current Duration PC#3: 35.80 ms
Gen. Output Current Duration: 36.35 ms

Delay Time of Trip Signal

Delay Time PC#1: - DNA
Delay Time PC#2: - DNA
Delay Time PC#3: - DNA

DNA = Data not acquired because the status signals were not functioning properly.

Thermal printer plots are submitted as an addendum to the report.

TABLE G16 - DRY ARC PROPAGATION TEST RESULTS FROM NEMA #3 HARNESS (#257) AND ILC DATA DEVICE CORPORATION POWER CONTROLLER

Power controller rated at 15 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.00	0.00	+0.02
Wire #2 : +270 Vdc	yes	0.00	0.00	+0.02
Wire #3 : -270 Vdc	yes	0.00	0.00	+0.02
Wire #4 : +270 Vdc	yes	0.00	0.00	+0.02
Wire #5 : -270 Vdc	yes	0.00	0.00	+0.02
Wire #6 : +270 Vdc	yes	0.00	0.00	+0.02
Wire #7 : -270 Vdc	yes	0.00	0.00	+0.02
AVERAGE :		0.00	0.00	+0.02

Notes:

There was no visible damage to the insulation was observed but conductor strand fusing was present.

Trip Time

Current Duration PC#1: 38.72 ms
Current Duration PC#2: 36.56 ms
Current Duration PC#3: 54.72 ms
Gen. Output Current Duration: 78.40 ms

Delay Time of Trip Signal

Delay Time PC#1: - DNA
Delay Time PC#2: - DNA
Delay Time PC#3: - DNA

DNA = Data not acquired because the status signals were not functioning properly.

Thermal printer plots are submitted as an addendum to the report.

TABLE G17 - DRY ARC PROPAGATION TEST RESULTS FROM M22759 HARNESS (#207) AND ILC DATA DEVICE CORPORATION POWER CONTROLLER

Power controller rated at 15 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.02	0.25	+0.02
Wire #2 : +270 Vdc	yes	0.00	0.25	-0.02
Wire #3 : -270 Vdc	yes	0.03	0.25	+0.03
Wire #4 : +270 Vdc	yes	0.00	0.25	+0.02
Wire #5 : -270 Vdc	yes	0.00	0.25	+0.02
Wire #6 : +270 Vdc	yes	0.00	0.25	-0.02
Wire #7 : -270 Vdc	yes	0.02	0.25	+0.02
AVERAGE :		0.01	0.25	+0.01

Notes:

An average of 0.25 inches of a black carbon residue and charring was observed at the shorting end of the harness. Conductor strand fusing was present.

Trip Time

Current Duration PC#1: 36.64 ms
Current Duration PC#2: 36.00 ms
Current Duration PC#3: 36.80 ms
Gen. Output Current Duration: 37.25 ms

Delay Time of Trip Signal

Delay Time PC#1: - DNA
Delay Time PC#2: - DNA
Delay Time PC#3: - DNA

DNA = Data not acquired because the status signals were not functioning properly.

Thermal printer plots are submitted as an addendum to the report.

TABLE G18 - DRY ARC PROPAGATION TEST RESULTS FROM M81381 HARNESS (#202) AND ILC DATA DEVICE CORPORATION POWER CONTROLLER

Power controller rated at 15 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.00	0.00	+0.02
Wire #2 : +270 Vdc	yes	0.00	0.00	+0.02
Wire #3 : -270 Vdc	yes	0.00	0.00	+0.02
Wire #4 : +270 Vdc	yes	0.00	0.00	+0.02
Wire #5 : -270 Vdc	yes	0.00	0.00	+0.02
Wire #6 : +270 Vdc	yes	0.00	0.00	+0.02
Wire #7 : -270 Vdc	yes	0.00	0.00	+0.02
AVERAGE :		0.00	0.00	+0.02

Notes:

There was a slight amount of darkening of the conductors observed on the shorting face of the harness and conductor strand fusing was observed.

Trip Time

Current Duration PC#1: 3.370 ms
Current Duration PC#2: 3.360 ms
Current Duration PC#3: 3.260 ms
Gen. Output Current Duration: 3.370 ms

Delay Time of Trip Signal

Delay Time PC#1: - DNA
Delay Time PC#2: - DNA
Delay Time PC#3: - DNA

DNA = Data not acquired because the status signals were not functioning properly.

Thermal printer plots are submitted as an addendum to the report.

TABLE G19 - DRY ARC PROPAGATION TEST RESULTS FROM FILOTEX HARNESS (#237) AND KILOVAC POWER CONTROLLER

Power controller rated at 15 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	1.25	0.25	0.03
Wire #2 : +270 Vdc	yes	0.00	1.50	-0.02
Wire #3 : -270 Vdc	yes	0.00	1.50	+0.03
Wire #4 : +270 Vdc	yes	0.00	1.50	-0.02
Wire #5 : -270 Vdc	yes	1.25	0.25	-0.03
Wire #6 : +270 Vdc	yes	1.25	0.25	-0.05
Wire #7 : -270 Vdc	yes	1.25	0.25	+0.02
AVERAGE :		0.71	0.79	-0.01

Notes:

In addition to the damage stated, wire #6 exhibited damage throughout the length of the harness. The outer tape wrap separated. Conductor strand fusing was clearly present.

Trip Time

Current Duration PC#1: 268.8 ms
Current Duration PC#2: 272.0 ms
Current Duration PC#3: 272.0 ms
Gen. Output Current Duration: 272.0 ms

Delay Time of Trip Signal

Delay Time PC#1: - PC did not trip
Delay Time PC#2: - PC did not trip
Delay Time PC#3: - PC did not trip

Thermal printer plots are submitted as an addendum to the report.

TABLE G20 - DRY ARC PROPAGATION TEST RESULTS FROM TENSOLITE HARNESS (#242) AND KILOVAC POWER CONTROLLER

Power controller rated at 15 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	1.00	0.50	-0.02
Wire #2 : +270 Vdc	yes	1.00	0.50	-0.05
Wire #3 : -270 Vdc	yes	0.50	0.50	+0.05
Wire #4 : +270 Vdc	yes	1.00	0.50	-0.02
Wire #5 : -270 Vdc	yes	1.00	0.50	+0.02
Wire #6 : +270 Vdc	yes	1.00	0.50	+0.03
Wire #7 : -270 Vdc	yes	1.00	0.50	+0.02
AVERAGE :		0.93	0.50	±0.00

Notes:

An average of 0.5 inches of a black carbon residue and charring was observed at the remainder of the shorting end of the harness. Conductor strand fusing was present.

Trip Time

Current Duration PC#1: 564.8 ms
Current Duration PC#2: 564.8 ms
Current Duration PC#3: 566.8 ms
Gen. Output Current Duration: 568.0 ms

Delay Time of Trip Signal

Delay Time PC#1: - PC did not trip
Delay Time PC#2: - PC did not trip
Delay Time PC#3: - PC did not trip

Thermal printer plots are submitted as an addendum to the report.

TABLE G21 - DRY ARC PROPAGATION TEST RESULTS FROM THERMATICS HARNESS (#247) AND KILOVAC POWER CONTROLLER

Power controller rated at 15 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	no	1.00	47.00	+0.02
Wire #2 : +270 Vdc	no	1.00	47.00	-0.06
Wire #3 : -270 Vdc	no	0.50	47.50	+0.02
Wire #4 : +270 Vdc	no	1.00	47.00	+0.03
Wire #5 : -270 Vdc	no	1.00	47.00	+0.02
Wire #6 : +270 Vdc	no	1.00	47.00	-0.05
Wire #7 : -270 Vdc	no	1.00	47.00	-0.02
AVERAGE :		0.93	47.07	-0.01

Notes:

There was severe damage observed throughout the length of the harness. The damage consisted of a black carbon residue and charring of the insulation. There was no continuity in the harness because the individual wires broke at approximately six inches from the terminal strip. The harness became very stiff and brittle which appears to have resulted from thermal degradation.

Trip Time

Current Duration PC#1: 1427 ms
Current Duration PC#2: 1449 ms
Current Duration PC#3: 1482 ms
Gen. Output Current Duration: 1482 ms

Delay Time of Trip Signal

Delay Time PC#1: - PC did not trip
Delay Time PC#2: - PC did not trip
Delay Time PC#3: - PC did not trip

Thermal printer plots are submitted as an addendum to the report.

TABLE G22 - DRY ARC PROPAGATION TEST RESULTS FROM NEMA #3 HARNESS (#257) AND KILOVAC POWER CONTROLLER

Power controller rated at 15 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	1.00	0.63	+0.02
Wire #2 : +270 Vdc	yes	1.00	0.63	-0.06
Wire #3 : -270 Vdc	yes	0.50	1.25	+0.02
Wire #4 : +270 Vdc	yes	1.00	0.63	+0.03
Wire #5 : -270 Vdc	yes	1.00	0.63	+0.02
Wire #6 : +270 Vdc	yes	1.00	0.63	-0.05
Wire #7 : -270 Vdc	yes	1.00	0.63	-0.02
AVERAGE :		0.93	0.72	-0.01

Notes:

An average of 0.72 inches of a black carbon residue was observed at the remainder of the shorting end of the harness. Conductor strand fusing was present.

Trip Time

Current Duration PC#1: 556.8 ms
Current Duration PC#2: 558.4 ms
Current Duration PC#3: 556.8 ms
Gen. Output Current Duration: 558.4 ms

Delay Time of Trip Signal

Delay Time PC#1: - PC did not trip
Delay Time PC#2: - PC did not trip
Delay Time PC#3: - PC did not trip

Thermal printer plots are submitted as an addendum to the report.

TABLE G23 - DRY ARC PROPAGATION TEST RESULTS FROM M22759 HARNESS (#207) AND KILOVAC POWER CONTROLLER

Power controller rated at 15 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	1.38	0.50	+0.02
Wire #2 : +270 Vdc	yes	1.88	0.50	-0.03
Wire #3 : -270 Vdc	yes	1.38	0.50	-0.03
Wire #4 : +270 Vdc	yes	1.63	0.50	-0.03
Wire #5 : -270 Vdc	yes	1.38	0.50	+0.02
Wire #6 : +270 Vdc	yes	1.38	0.50	-0.03
Wire #7 : -270 Vdc	yes	1.38	0.50	-0.02
AVERAGE :		1.49	0.50	-0.01

Notes:

An average of 0.5 inches of a black carbon residue was observed at the remainder of the shorting end of the harness. Conductor strand fusing was present.

Trip Time

Current Duration PC#1: 388.8 ms
Current Duration PC#2: 388.8 ms
Current Duration PC#3: 390.4 ms
Gen. Output Current Duration: 390.4 ms

Delay Time of Trip Signal

Delay Time PC#1: - PC did not trip
Delay Time PC#2: - PC did not trip
Delay Time PC#3: - PC did not trip

Thermal printer plots are submitted as an addendum to the report.

TABLE G24 - DRY ARC PROPAGATION TEST RESULTS FROM M81381 HARNESS (#202) AND KILOVAC POWER CONTROLLER

Power controller rated at 15 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	3.63	0.50	+0.08
Wire #2 : +270 Vdc	yes	4.38	0.00	-0.02
Wire #3 : -270 Vdc	yes	3.88	0.31	+0.05
Wire #4 : +270 Vdc	yes	4.38	0.09	-0.05
Wire #5 : -270 Vdc	yes	3.13	1.00	+0.09
Wire #6 : +270 Vdc	yes	2.63	1.50	+0.03
Wire #7 : -270 Vdc	yes	3.00	0.03	+0.09
AVERAGE :		3.58	0.49	+0.04

Notes:

An average of 0.49 inches of insulation charring was observed at the remainder of the shorting end of the harness. Conductor strand fusing was present. The powered conductors within the harness changed to a darker color which appears to have resulted from thermal degradation.

Trip Time

Current Duration PC#1: 1129 ms
Current Duration PC#2: 1123 ms
Current Duration PC#3: 1129 ms
Gen. Output Current Duration: 1130 ms

Delay Time of Trip Signal

Delay Time PC#1: - PC did not trip
Delay Time PC#2: - PC did not trip
Delay Time PC#3: - PC did not trip

Thermal printer plots are submitted as an addendum to the report.

TABLE G25 - DRY ARC PROPAGATION TEST RESULTS FROM FILOTEX HARNESS (#236) AND EATON POWER CONTROLLER

Power controller rated at 40 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.00	0.00	0.00
Wire #2 : +270 Vdc	yes	0.00	0.25	-0.09
Wire #3 : -270 Vdc	yes	0.00	0.25	-0.08
Wire #4 : +270 Vdc	yes	0.00	0.25	0.00
Wire #5 : -270 Vdc	yes	0.00	0.25	-0.03
Wire #6 : +270 Vdc	yes	0.00	0.25	-0.05
Wire #7 : -270 Vdc	yes	0.00	0.25	-0.03
AVERAGE :		0.00	0.21	-0.04

Notes:

An average of 0.21 inches of a black carbon residue was observed at the shorting end of the harness. Slight darkening of conductors was observed on the shorting face of the harness with conductor strand fusing present in addition to the damage stated above.

Trip Time

Current Duration PC#1: 172.0 ms
Current Duration PC#2: 68.4 ms
Current Duration PC#3: 143.6 ms
Gen. Output Current Duration: 195.2 ms

Delay Time of Trip Signal

Delay Time PC#1: -7.100 ms
Delay Time PC#2: -6.200 ms
Delay Time PC#3: -3.700 ms

Thermal printer plots are submitted as an addendum to the report.

TABLE G26 - DRY ARC PROPAGATION TEST RESULTS FROM TENSOLITE HARNESS (#241) AND EATON POWER CONTROLLER

Power controller rated at 40 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.00	0.00	+0.02
Wire #2 : +270 Vdc	yes	0.00	0.25	-0.03
Wire #3 : -270 Vdc	yes	0.00	0.25	0.00
Wire #4 : +270 Vdc	yes	0.00	0.25	+0.02
Wire #5 : -270 Vdc	yes	0.00	0.25	+0.02
Wire #6 : +270 Vdc	yes	0.00	0.25	+0.03
Wire #7 : -270 Vdc	yes	0.00	0.25	+0.02
AVERAGE :		0.00	0.21	+0.01

Notes:
An average of 0.25 inches of a black carbon residue was observed at the shorting end of the harness. Conductor strand fusing was also present.

Trip Time
Current Duration PC#1: 105.9 ms
Current Duration PC#2: 150.7 ms
Current Duration PC#3: 150.7 ms
Gen. Output Current Duration: 151.0 ms

Delay Time of Trip Signal
Delay Time PC#1: -7.040 ms
Delay Time PC#2: -8.000 ms
Delay Time PC#3: -3.960 ms

Thermal printer plots are submitted as an addendum to the report.

TABLE G27 - DRY ARC PROPAGATION TEST RESULTS FROM THERMATICS HARNESS (#246) AND EATON POWER CONTROLLER

Power controller rated at 40 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.00	0.25	+0.02
Wire #2 : +270 Vdc	yes	0.00	0.25	-0.02
Wire #3 : -270 Vdc	yes	0.00	0.25	+0.02
Wire #4 : +270 Vdc	yes	0.00	0.25	-0.03
Wire #5 : -270 Vdc	yes	0.00	0.25	+0.02
Wire #6 : +270 Vdc	yes	0.00	0.25	0.00
Wire #7 : -270 Vdc	yes	0.00	0.25	+0.02
AVERAGE :		0.00	0.25	±0.00

Notes:

An average of 0.25 inches of a black carbon residue was observed at the shorting end of the harness. Conductor strand fusing was also present.

Trip Time

Current Duration PC#1: 150.4 ms
Current Duration PC#2: 68.2 ms
Current Duration PC#3: 65.6 ms
Gen. Output Current Duration: 150.4 ms

Delay Time of Trip Signal

Delay Time PC#1: PC did not trip
Delay Time PC#2: -6.000 ms
Delay Time PC#3: -7.680 ms

Thermal printer plots are submitted as an addendum to the report.

TABLE G28 - DRY ARC PROPAGATION TEST RESULTS FROM NEMA #3 HARNESS (#256) AND EATON POWER CONTROLLER

Power controller rated at 40 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.00	0.25	-0.02
Wire #2 : +270 Vdc	yes	0.00	0.25	+0.02
Wire #3 : -270 Vdc	yes	0.00	0.25	-0.03
Wire #4 : +270 Vdc	yes	0.00	0.25	-0.03
Wire #5 : -270 Vdc	yes	0.00	0.25	+0.02
Wire #6 : +270 Vdc	yes	0.00	0.25	+0.02
Wire #7 : -270 Vdc	yes	0.00	0.25	+0.05
AVERAGE :		0.00	0.25	±0.00

Notes:

An average of 0.25 inches of a black carbon residue was observed at the shorting end of the harness. Conductor strand fusing was also present.

Trip Time

Current Duration PC#1: 107.8 ms
Current Duration PC#2: 123.5 ms
Current Duration PC#3: 103.7 ms
Gen. Output Current Duration: 143.0 ms

Delay Time of Trip Signal

Delay Time PC#1: -4.520 ms
Delay Time PC#2: -7.200 ms
Delay Time PC#3: -3.960 ms

Thermal printer plots are submitted as an addendum to the report.

TABLE G29 - DRY ARC PROPAGATION TEST RESULTS FROM M22759 HARNESS (#206) AND EATON POWER CONTROLLER

Power controller rated at 40 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.00	0.25	+0.02
Wire #2 : +270 Vdc	yes	0.00	0.25	-0.02
Wire #3 : -270 Vdc	yes	0.00	0.25	+0.02
Wire #4 : +270 Vdc	yes	0.00	0.25	+0.03
Wire #5 : -270 Vdc	yes	0.00	0.25	+0.03
Wire #6 : +270 Vdc	yes	0.00	0.25	+0.05
Wire #7 : -270 Vdc	yes	0.00	0.25	+0.03
AVERAGE :		0.00	0.25	+0.02

Notes:

An average of 0.25 inches of a black carbon residue was observed at the shorting end of the harness. Conductor strand fusing was also present.

Trip Time

Current Duration PC#1: 101.8 ms
Current Duration PC#2: 72.0 ms
Current Duration PC#3: 92.0 ms
Gen. Output Current Duration: 127.0 ms

Delay Time of Trip Signal

Delay Time PC#1: -6.240 ms
Delay Time PC#2: -4.160 ms
Delay Time PC#3: -5.280 ms

Thermal printer plots are submitted as an addendum to the report.

TABLE G30 - DRY ARC PROPAGATION TEST RESULTS FROM M81381 HARNESS (#201) AND EATON POWER CONTROLLER

Power controller rated at 40 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.00	0.25	+0.02
Wire #2 : +270 Vdc	yes	0.00	0.25	-0.02
Wire #3 : -270 Vdc	yes	0.00	0.25	-0.02
Wire #4 : +270 Vdc	yes	0.00	0.25	-0.02
Wire #5 : -270 Vdc	yes	0.00	0.25	-0.02
Wire #6 : +270 Vdc	yes	0.00	0.25	+0.05
Wire #7 : -270 Vdc	yes	0.00	0.25	+0.05
AVERAGE :		0.00	0.25	+0.01

Notes:

An average of 0.25 inches of a black carbon residue was observed at the shorting end of the harness. Conductor strand fusing was also present.

Trip Time

Current Duration PC#1: 163.2 ms
Current Duration PC#2: 110.1 ms
Current Duration PC#3: 74.2 ms
Gen. Output Current Duration: 163.8 ms

Delay Time of Trip Signal

Delay Time PC#1: -8.000 ms
Delay Time PC#2: -4.300 ms
Delay Time PC#3: -4.080 ms

Thermal printer plots are submitted as an addendum to the report.

TABLE G31 - DRY ARC PROPAGATION TEST RESULTS FROM FILOTEX HARNESS (#236) AND HARTMAN POWER CONTROLLER

Power controller rated at 40 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.00	0.00	0.00
Wire #2 : +270 Vdc	yes	0.00	0.25	+0.02
Wire #3 : -270 Vdc	yes	0.00	0.25	+0.03
Wire #4 : +270 Vdc	yes	0.00	0.00	+0.02
Wire #5 : -270 Vdc	yes	0.00	0.13	0.00
Wire #6 : +270 Vdc	yes	0.00	0.13	+0.02
Wire #7 : -270 Vdc	yes	0.00	0.00	-0.02
AVERAGE :		0.00	0.11	+0.01

Notes:

An average of 0.11 inches of a black carbon residue was observed one side of the harness at the shorting end. Conductor strand fusing was also present.

Trip Time

Current Duration PC#1: 59.40 ms
Current Duration PC#2: 21.50 ms
Current Duration PC#3: 57.60 ms
Gen. Output Current Duration: 59.60 ms

Delay Time of Trip Signal

Delay Time PC#1: -22.00 ms
Delay Time PC#2: -16.80 ms
Delay Time PC#3: -15.80 ms

Thermal printer plots are submitted as an addendum to the report.

TABLE G32 - DRY ARC PROPAGATION TEST RESULTS FROM TENSOLITE HARNESS (#241) AND HARTMAN POWER CONTROLLER

Power controller rated at 40 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.06	0.25	+0.09
Wire #2 : +270 Vdc	yes	0.06	0.25	+0.03
Wire #3 : -270 Vdc	yes	0.03	0.25	0.00
Wire #4 : +270 Vdc	yes	0.03	0.50	+0.05
Wire #5 : -270 Vdc	yes	0.13	0.50	+0.03
Wire #6 : +270 Vdc	yes	0.25	0.13	-0.08
Wire #7 : -270 Vdc	yes	0.13	0.25	-0.06
AVERAGE :		0.10	0.30	+0.01

Notes:
An average of 0.30 inches of a black carbon residue was observed at the shorting end of the harness. Conductor strand fusing was also present.

Trip Time
Current Duration PC#1: 20.80 ms
Current Duration PC#2: 30.88 ms
Current Duration PC#3: 120.96 ms
Gen. Output Current Duration: 151.36 ms

Delay Time of Trip Signal
Delay Time PC#1: -16.48 ms
Delay Time PC#2: -12.92 ms
Delay Time PC#3: -115.52 ms

Thermal printer plots are submitted as an addendum to the report.

TABLE G33 - DRY ARC PROPAGATION TEST RESULTS FROM THERMATICS HARNESS (#246) AND HARTMAN POWER CONTROLLER

Power controller rated at 40 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.13	0.00	-0.06
Wire #2 : +270 Vdc	yes	0.13	0.02	-0.03
Wire #3 : -270 Vdc	yes	0.06	0.00	+0.02
Wire #4 : +270 Vdc	yes	0.06	0.02	+0.06
Wire #5 : -270 Vdc	yes	0.00	0.03	+0.06
Wire #6 : +270 Vdc	yes	0.00	0.02	+0.08
Wire #7 : -270 Vdc	yes	0.06	0.03	+0.09
AVERAGE :		0.06	0.02	+0.03

Notes:
There was darkening of conductors observed on the shorting face of the harness with conductor strand fusing present.

Trip Time
Current Duration PC#1: 138.9 ms
Current Duration PC#2: 21.2 ms
Current Duration PC#3: 21.4 ms
Gen. Output Current Duration: 160.0 ms

Delay Time of Trip Signal
Delay Time PC#1: -134.7 ms
Delay Time PC#2: -16.4 ms
Delay Time PC#3: -16.5 ms

Thermal printer plots are submitted as an addendum to the report.

TABLE G34 - DRY ARC PROPAGATION TEST RESULTS FROM NEMA #3 HARNESS (#256) AND HARTMAN POWER CONTROLLER

Power controller rated at 40 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.00	0.00	+0.03
Wire #2 : +270 Vdc	yes	0.00	0.25	+0.02
Wire #3 : -270 Vdc	yes	0.00	0.25	+0.02
Wire #4 : +270 Vdc	yes	0.00	0.25	+0.02
Wire #5 : -270 Vdc	yes	0.00	0.00	+0.02
Wire #6 : +270 Vdc	yes	0.00	0.00	+0.02
Wire #7 : -270 Vdc	yes	0.00	0.00	+0.02
AVERAGE :		0.00	0.11	+0.03

Notes:

The conductors of wires #2 and #3 are shorted together. Some darkening of conductors was observed on the shorting face of the harness with conductor strand fusing present. The average of 0.25 inches of a black carbon residue was observed on one side of the shorting end of the harness.

Trip Time

Current Duration PC#1: 22.40 ms
Current Duration PC#2: 50.88 ms
Current Duration PC#3: 50.56 ms
Gen. Output Current Duration: 50.88 ms

Delay Time of Trip Signal

Delay Time PC#1: -18.08 ms
Delay Time PC#2: -23.76 ms
Delay Time PC#3: -15.96 ms

Thermal printer plots are submitted as an addendum to the report.

TABLE G35 - DRY ARC PROPAGATION TEST RESULTS FROM M22759 HARNESS (#206) AND HARTMAN POWER CONTROLLER

Power controller rated at 40 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.00	0.25	+0.03
Wire #2 : +270 Vdc	yes	0.00	0.25	0.00
Wire #3 : -270 Vdc	yes	0.00	0.25	+0.02
Wire #4 : +270 Vdc	yes	0.00	0.25	+0.03
Wire #5 : -270 Vdc	yes	0.00	0.00	+0.02
Wire #6 : +270 Vdc	yes	0.00	0.25	+0.02
Wire #7 : -270 Vdc	yes	0.00	0.25	+0.02
AVERAGE :		0.00	0.21	+0.02

Notes:
An average of 0.21 inches of a black carbon residue was observed at the shorting end of the harness. There was some darkening of conductors observed on the shorting face of the harness with conductor strand fusing present.

Trip Time
Current Duration PC#1: 67.52 ms
Current Duration PC#2: 42.24 ms
Current Duration PC#3: 15.40 ms
Gen. Output Current Duration: 66.16 ms

Delay Time of Trip Signal
Delay Time PC#1: -20.96 ms
Delay Time PC#2: -20.96 ms
Delay Time PC#3: -10.56 ms

Thermal printer plots are submitted as an addendum to the report.

TABLE G36 - DRY ARC PROPAGATION TEST RESULTS FROM M81381 HARNESS (#201) AND HARTMAN POWER CONTROLLER

Power controller rated at 40 amps

	END TO END WIRE CONTINUITY CHECK (yes/no)	LENGTH OF HARNESS CONSUMED IN TEST (inches)	LENGTH OF CHARRED INSULATION POST TEST (inches)	LENGTH OF RECESSED(-) /EXPOSED(+) CONDUCTOR POST TEST (inches)
Wire #1 : -270 Vdc	yes	0.00	0.00	0.00
Wire #1 : -270 Vdc	yes	0.00	0.03	0.00
Wire #2 : +270 Vdc	yes	0.00	0.09	+0.02
Wire #3 : -270 Vdc	yes	0.00	0.02	0.00
Wire #4 : +270 Vdc	yes	0.00	0.03	-0.02
Wire #5 : -270 Vdc	yes	0.00	0.09	+0.02
Wire #6 : +270 Vdc	yes	0.00	0.02	+0.02
Wire #7 : -270 Vdc	yes	0.00	0.08	0.00
AVERAGE :		0.00	0.05	+0.01

Notes:

There was darkening of conductors observed on the shorting face of the harness with conductor strand fusing present.

Trip Time

Current Duration PC#1: 21.84 ms
Current Duration PC#2: 27.52 ms
Current Duration PC#3: 41.92 ms
Gen. Output Current Duration: 55.52 ms

Delay Time of Trip Signal

Delay Time PC#1: -17.44 ms
Delay Time PC#2: -22.40 ms
Delay Time PC#3: -15.76 ms

Thermal printer plots are submitted as an addendum to the report.

APPENDIX H

PHOTOGRAPHS OF PROTECTED TEST SPECIMENS

Inclusive pages: 147 - 182

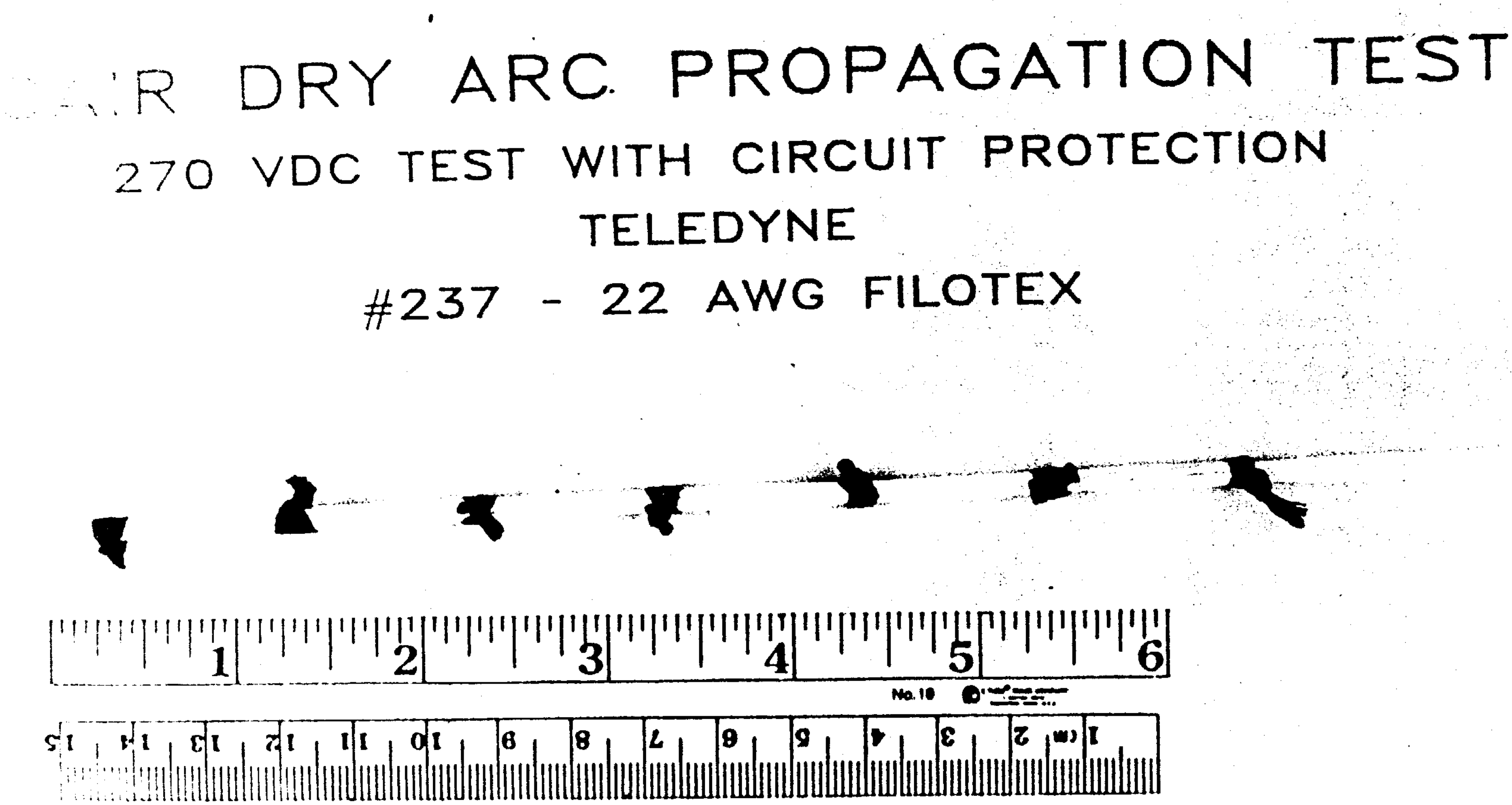


FIGURE H1 - FILOTEX (#237) HARNESS TESTED WITH TELEDYNE SOLID STATE POWER CONTROLLERS

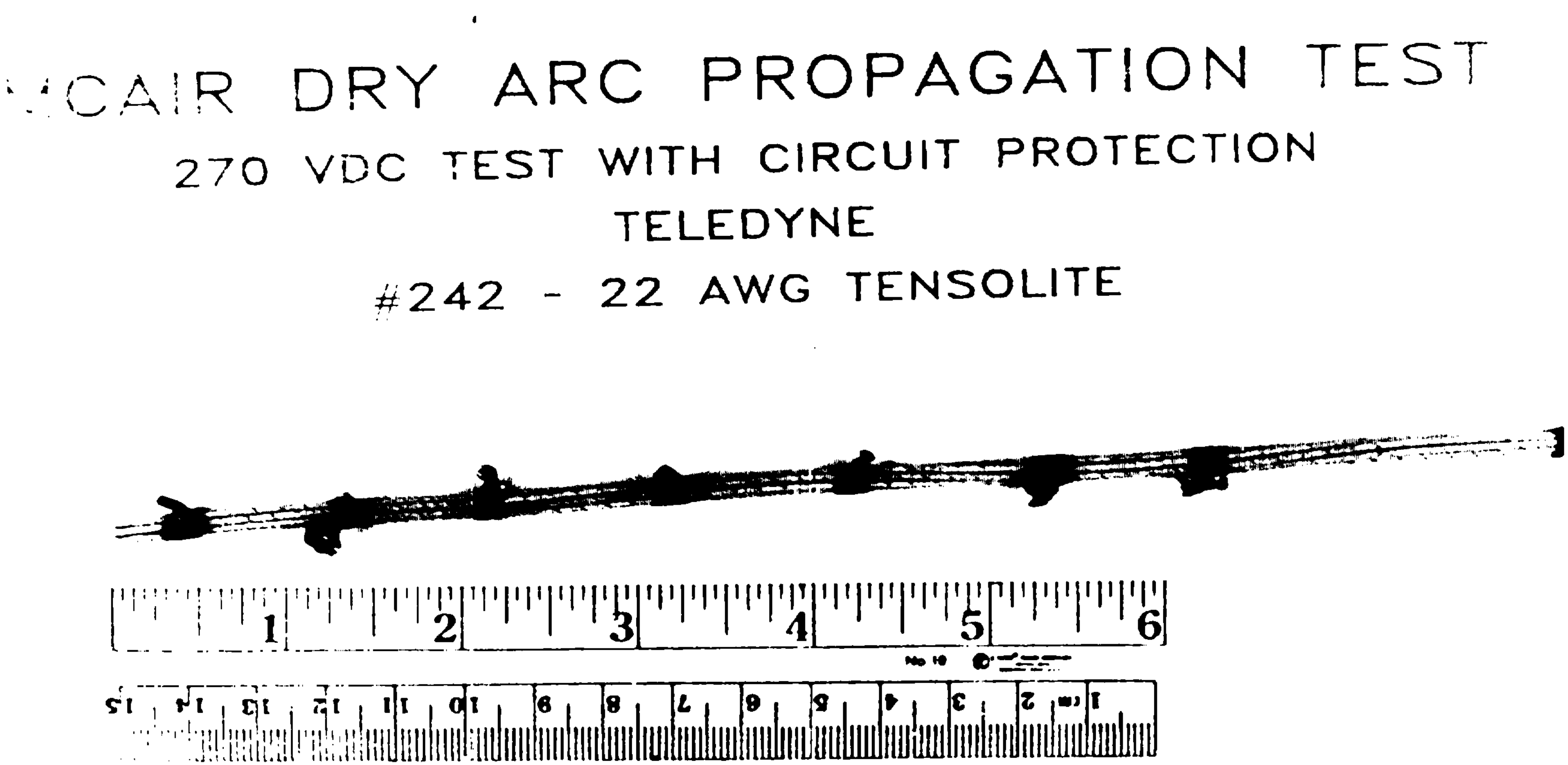


FIGURE H.7 - TENSOLITE (#242) HARNESS TESTED WITH TELEDYNE SOLID STATE POWER CONTROLLERS

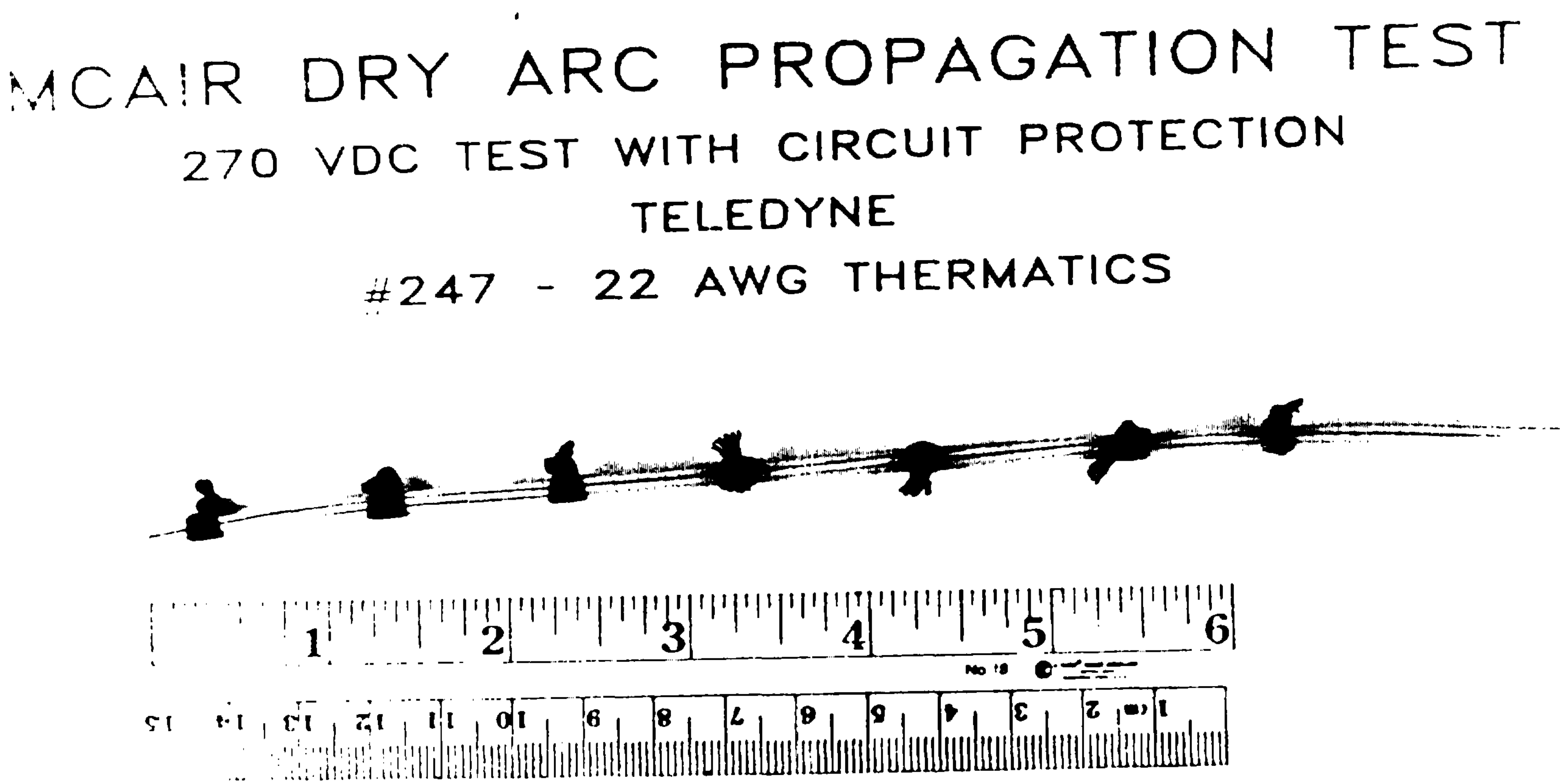


FIGURE H3 - THERMATICS (#247) HARNESS TESTED WITH TELEDYNE SOLID STATE POWER CONTROLLERS

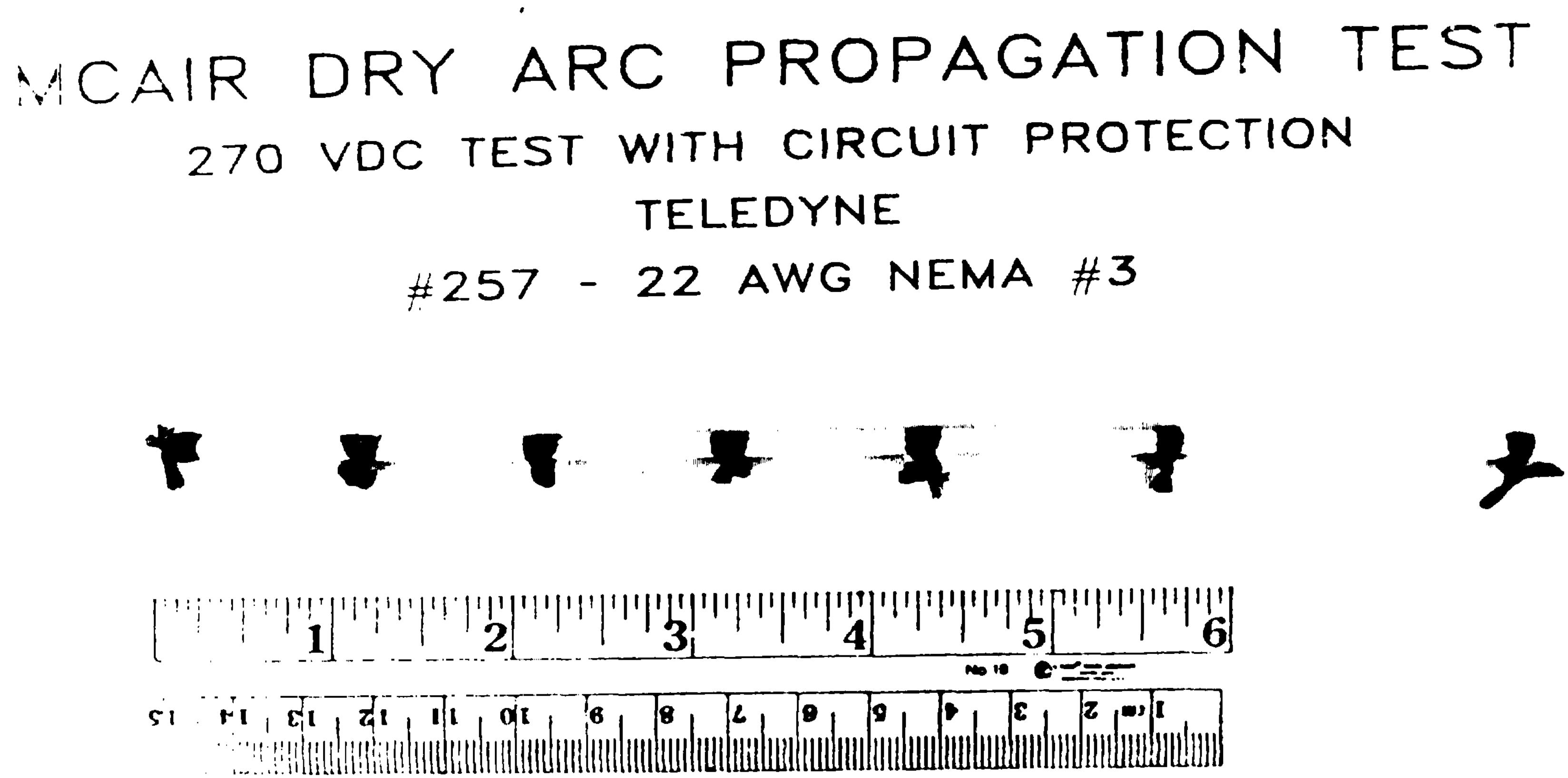


FIGURE H4 - NEMA #3 (#257) HARNESS TESTED WITH TELEDYNE SOLID STATE POWER CONTROLLERS

MCAIR DRY ARC PROPAGATION TEST

270 VDC TEST WITH CIRCUIT PROTECTION

TELEDYNE

#207 - 22 AWG M22759

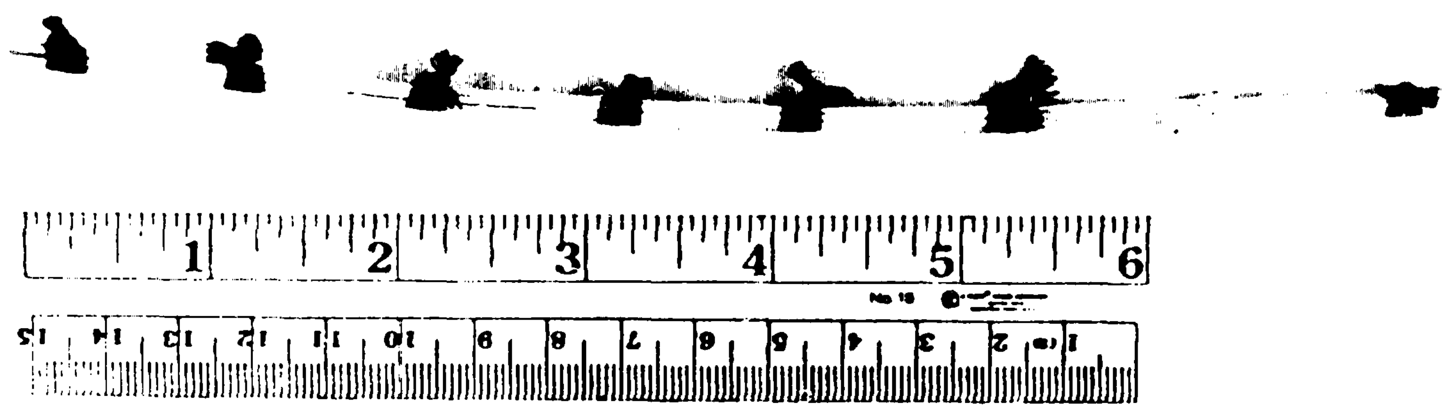


FIGURE H5 - M22759 (#207) HARNESS TESTED WITH TELEDYNE SOLID STATE POWER CONTROLLERS

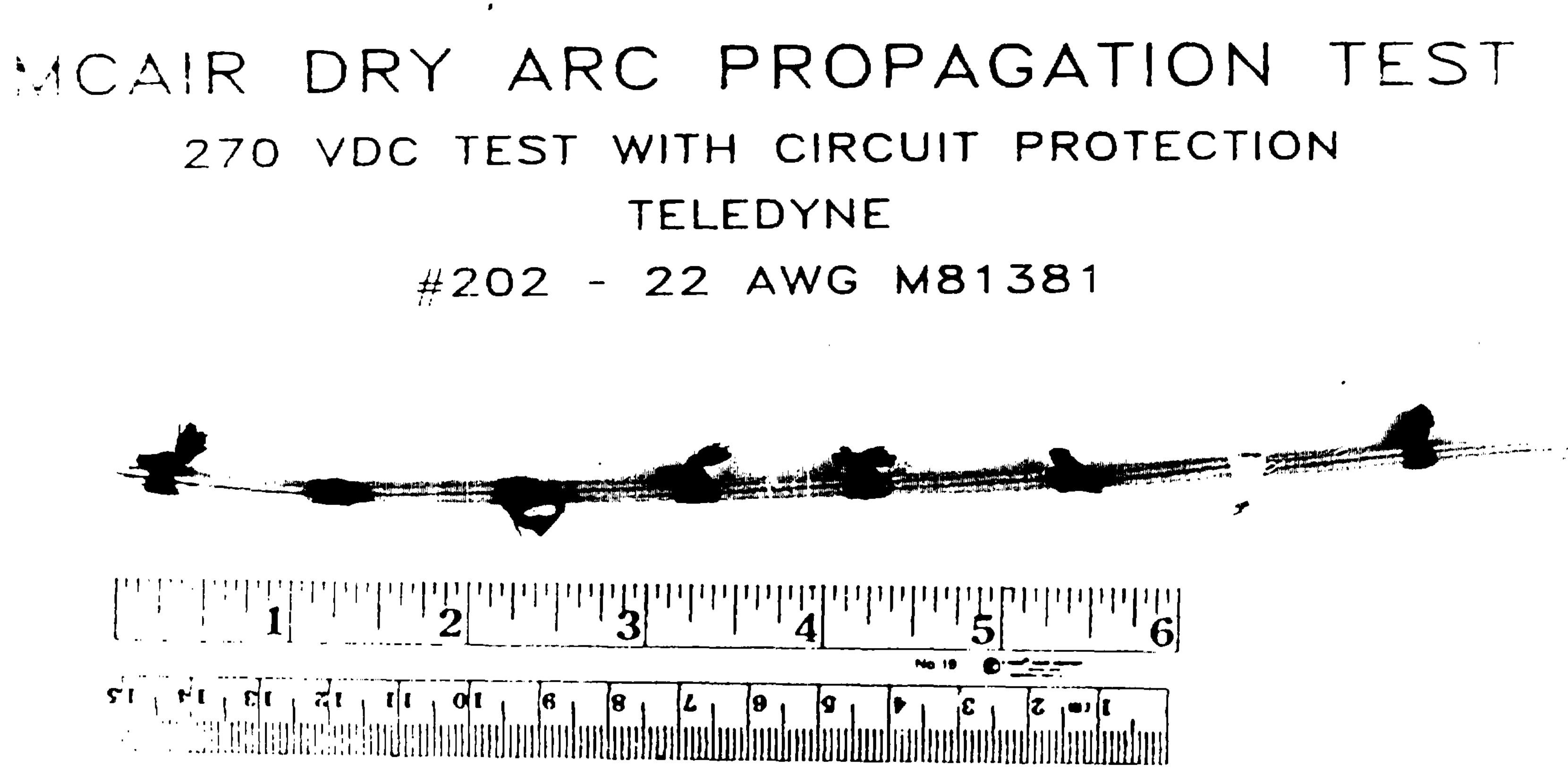


FIGURE H6 - M81381 (#202) HARNESS TESTED WITH TELEDYNE SOLID STATE POWER CONTROLLERS

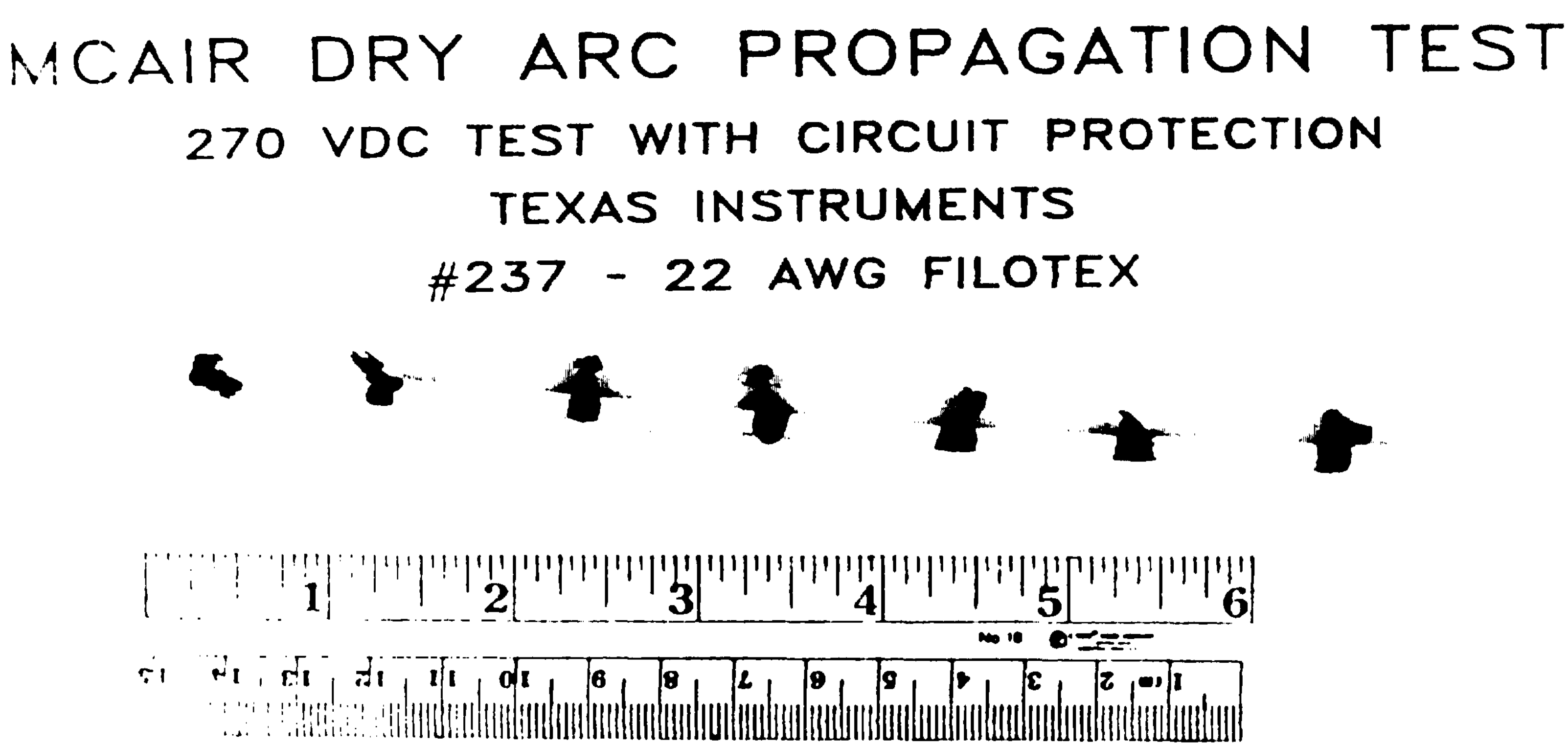


FIGURE H7 - FILOTEX (#237) HARNESS TESTED WITH TEXAS INSTRUMENTS POWER CONTROLLERS

MCAIR DRY ARC PROPAGATION TEST

270 VDC TEST WITH CIRCUIT PROTECTION

TEXAS INSTRUMENTS

#242 - 22 AWG TENSOLITE

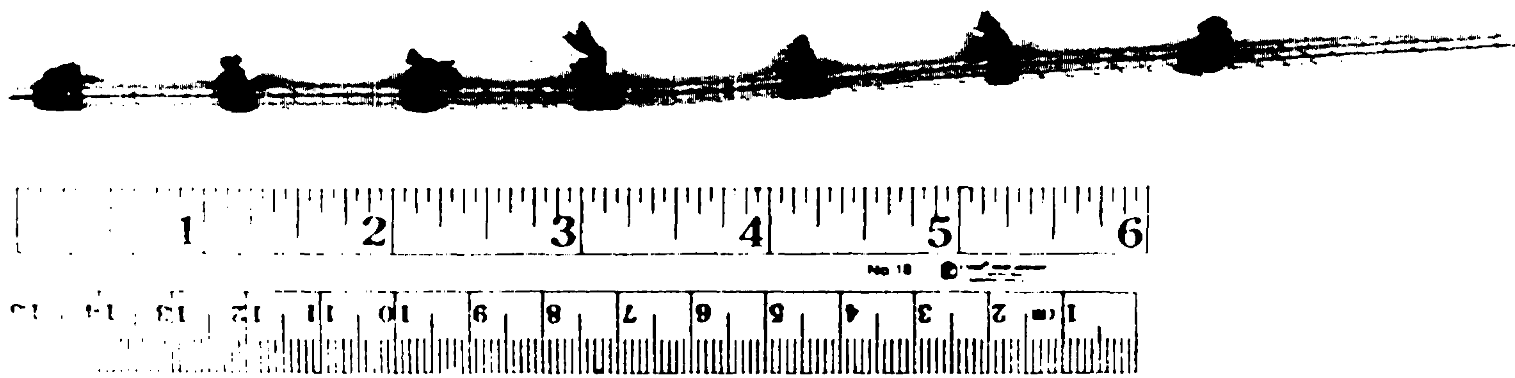


FIGURE B8 - TENSOLITE (#242) HARNESS TESTED WITH TEXAS INSTRUMENTS POWER CONTROLLERS

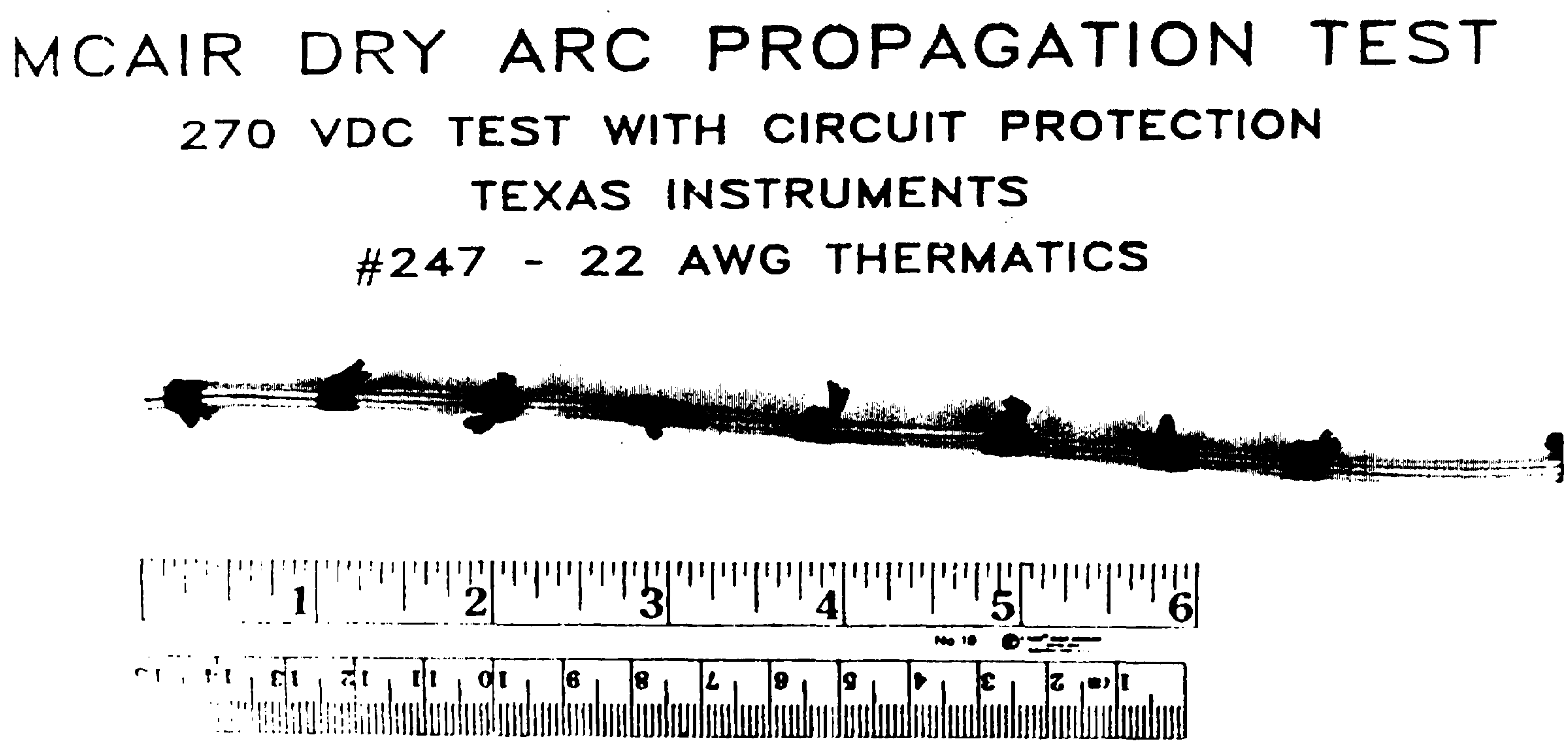


FIGURE H9 - THERMATICS (#247) HARNESS TESTED WITH TEXAS INSTRUMENTS POWER CONTROLLERS

MCAIR DRY ARC PROPAGATION TEST

270 VDC TEST WITH CIRCUIT PROTECTION

TEXAS INSTRUMENTS

#257 - 22 AWG NEMA #3

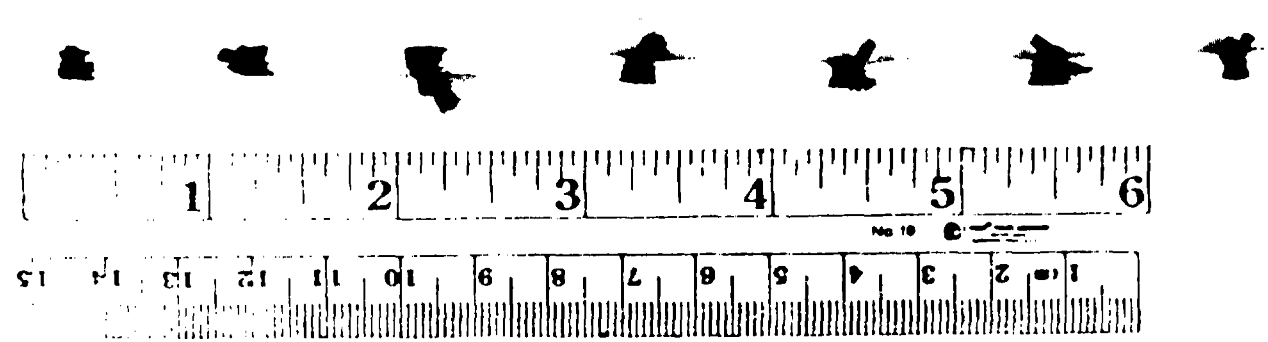


FIGURE H10 - NEMA #3 (#257) HARNESS TESTED WITH TEXAS INSTRUMENTS POWER CONTROLLERS

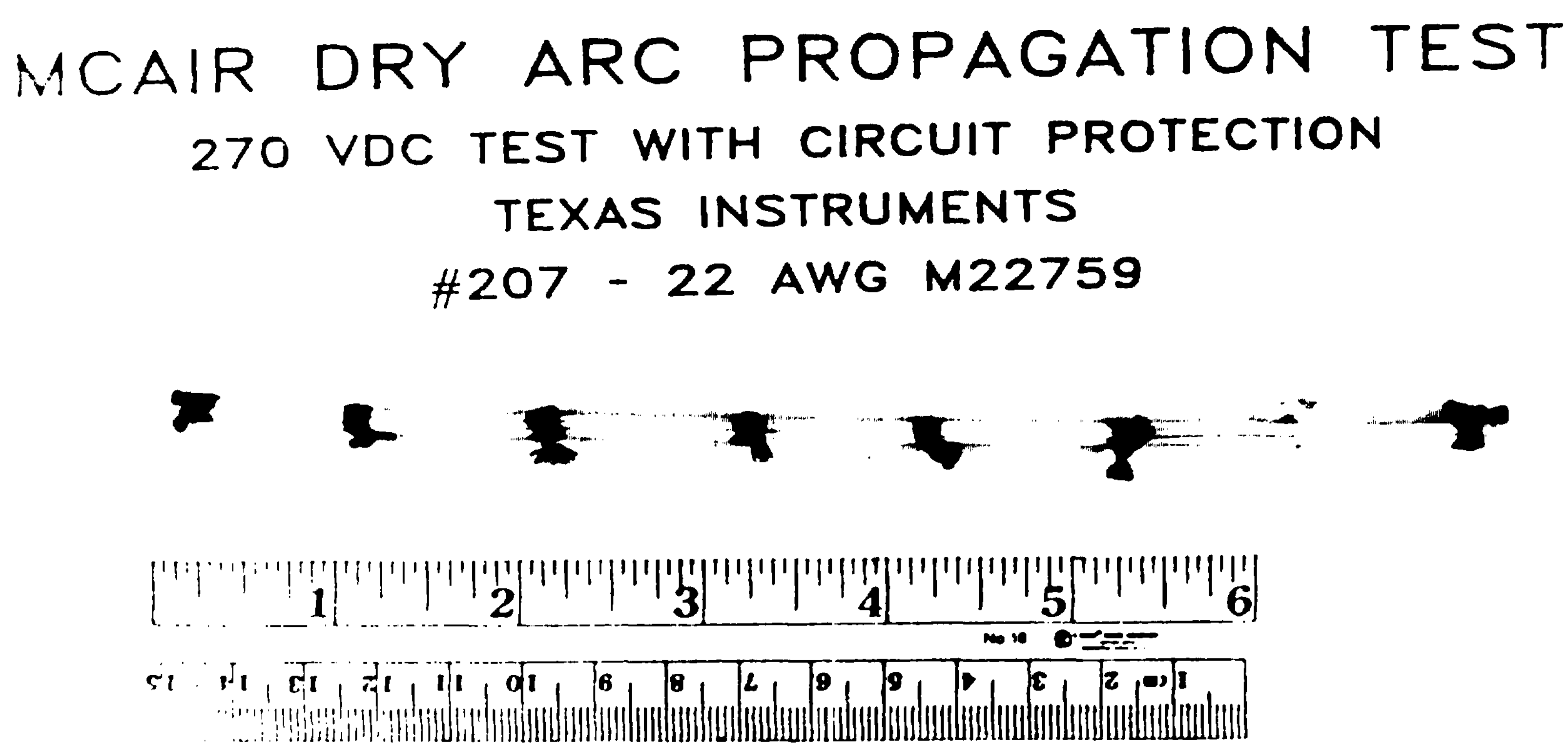


FIGURE H11 - M22759 (#207) HARNESS TESTED WITH TEXAS INSTRUMENTS POWER CONTROLLERS

MCAIR DRY ARC PROPAGATION TEST

270 VDC TEST WITH CIRCUIT PROTECTION

TEXAS INSTRUMENTS

#202 - 22 AWG M81381

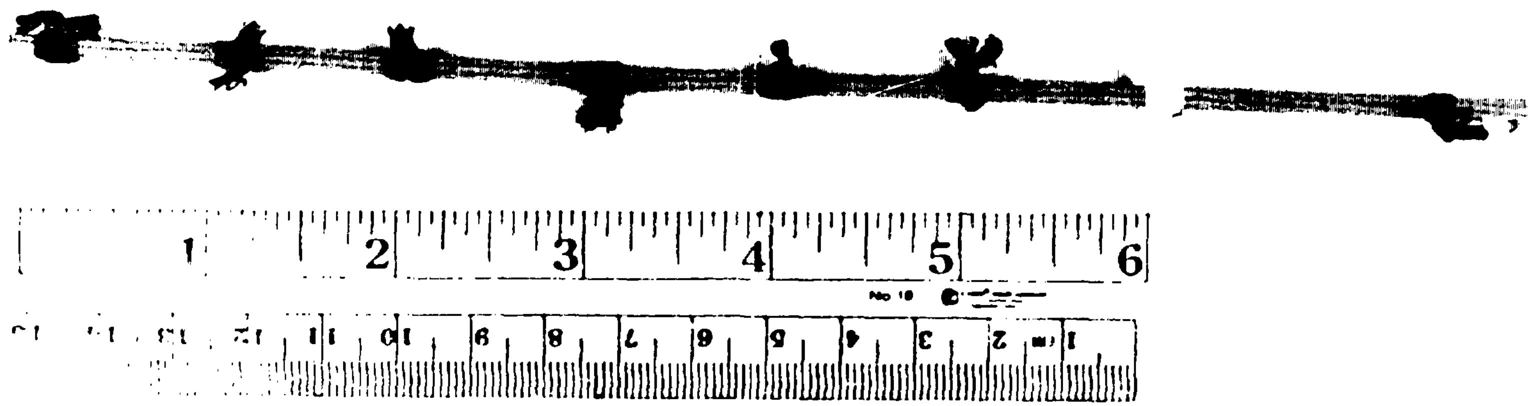


FIGURE H12 - M81381 (#202) HARNESS TESTED WITH TEXAS INSTRUMENTS POWER CONTROLLERS

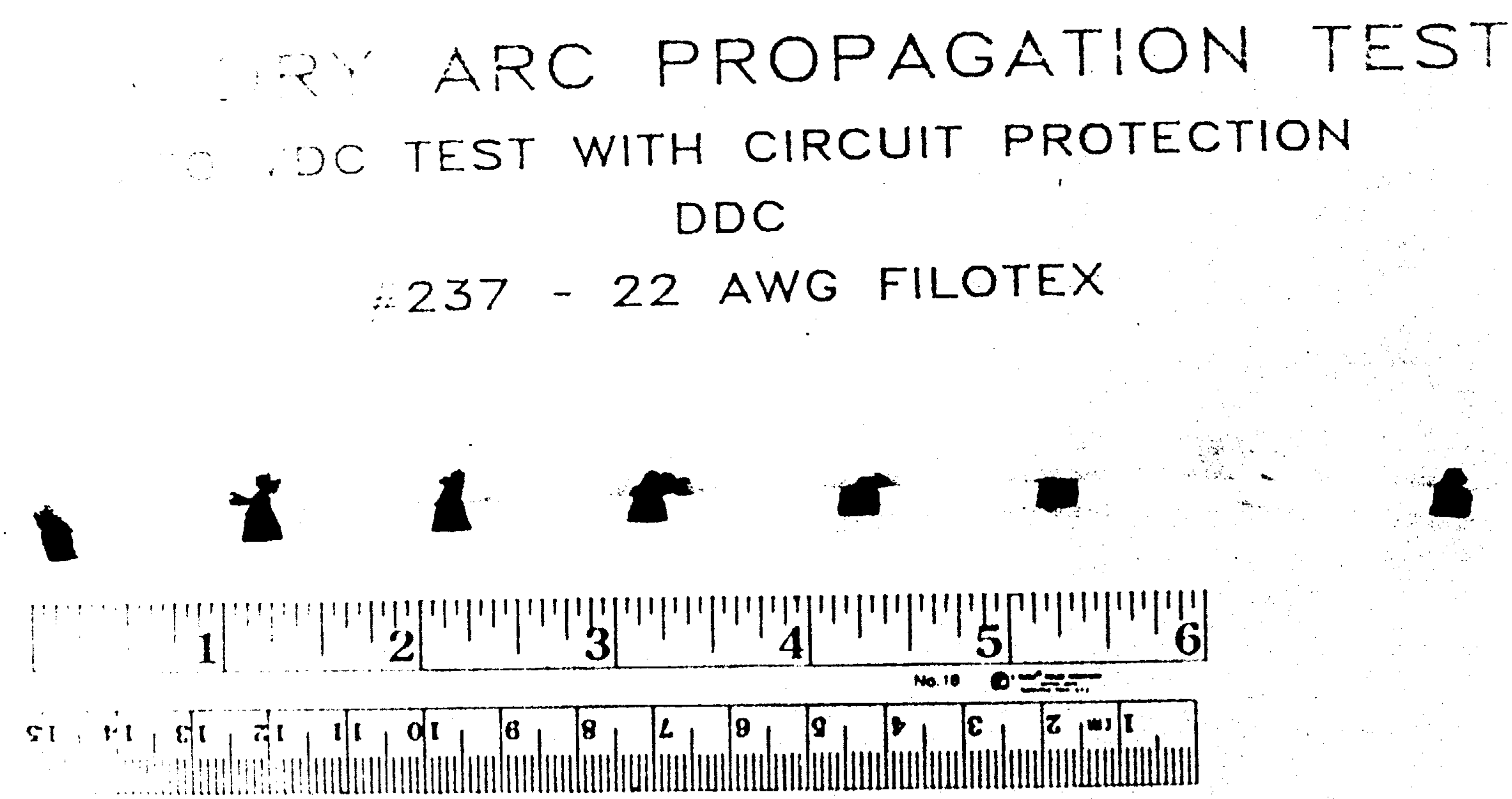


FIGURE H13 - FILOTEX (#237) HARNESS TESTED WITH ILC DATA DEVICE CORPORATION POWER CONTROLLERS

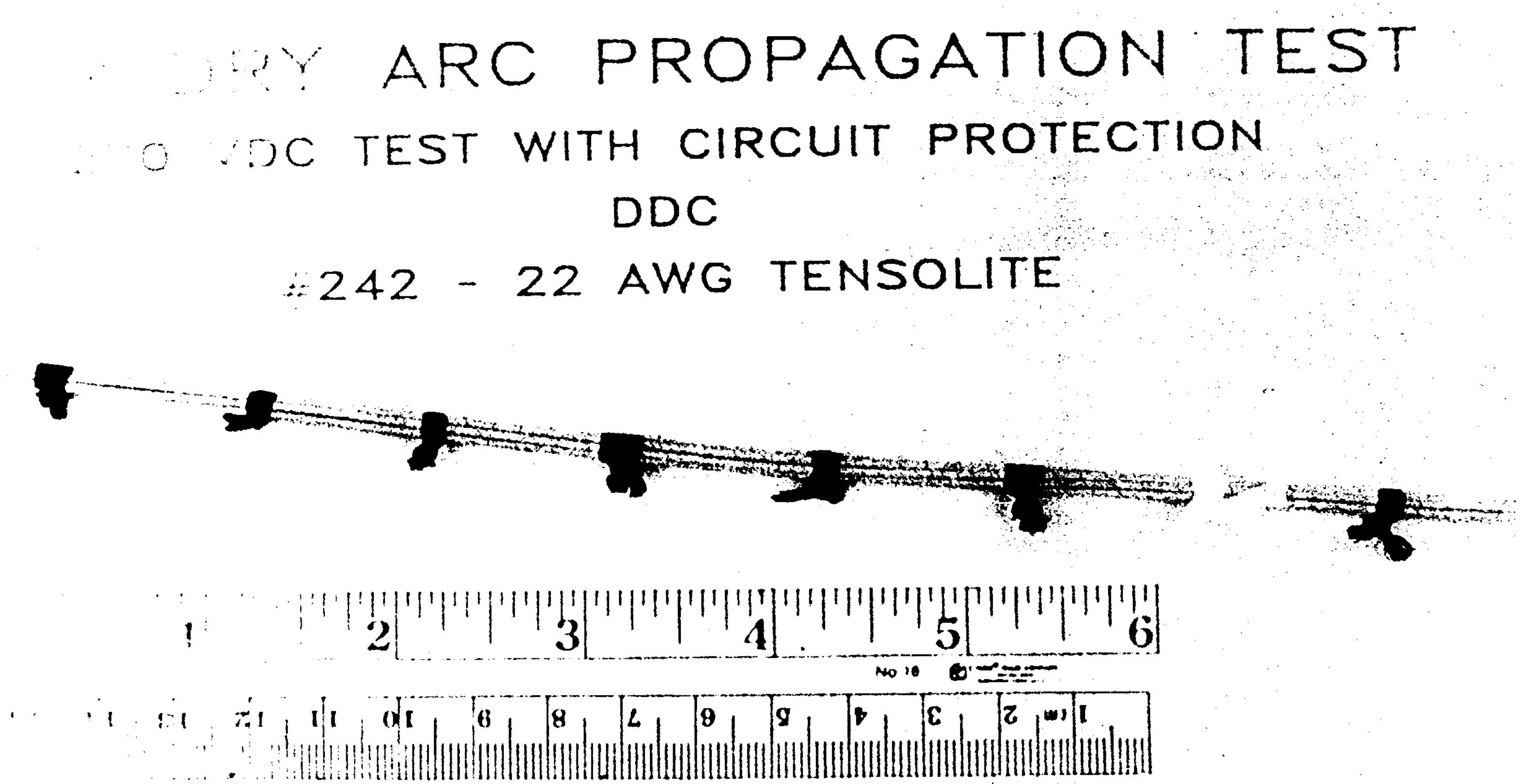


FIGURE H14 - TENSOLITE (#242) HARNESS TESTED WITH ILC DATA DEVICE CORPORATION POWER CONTROLLERS

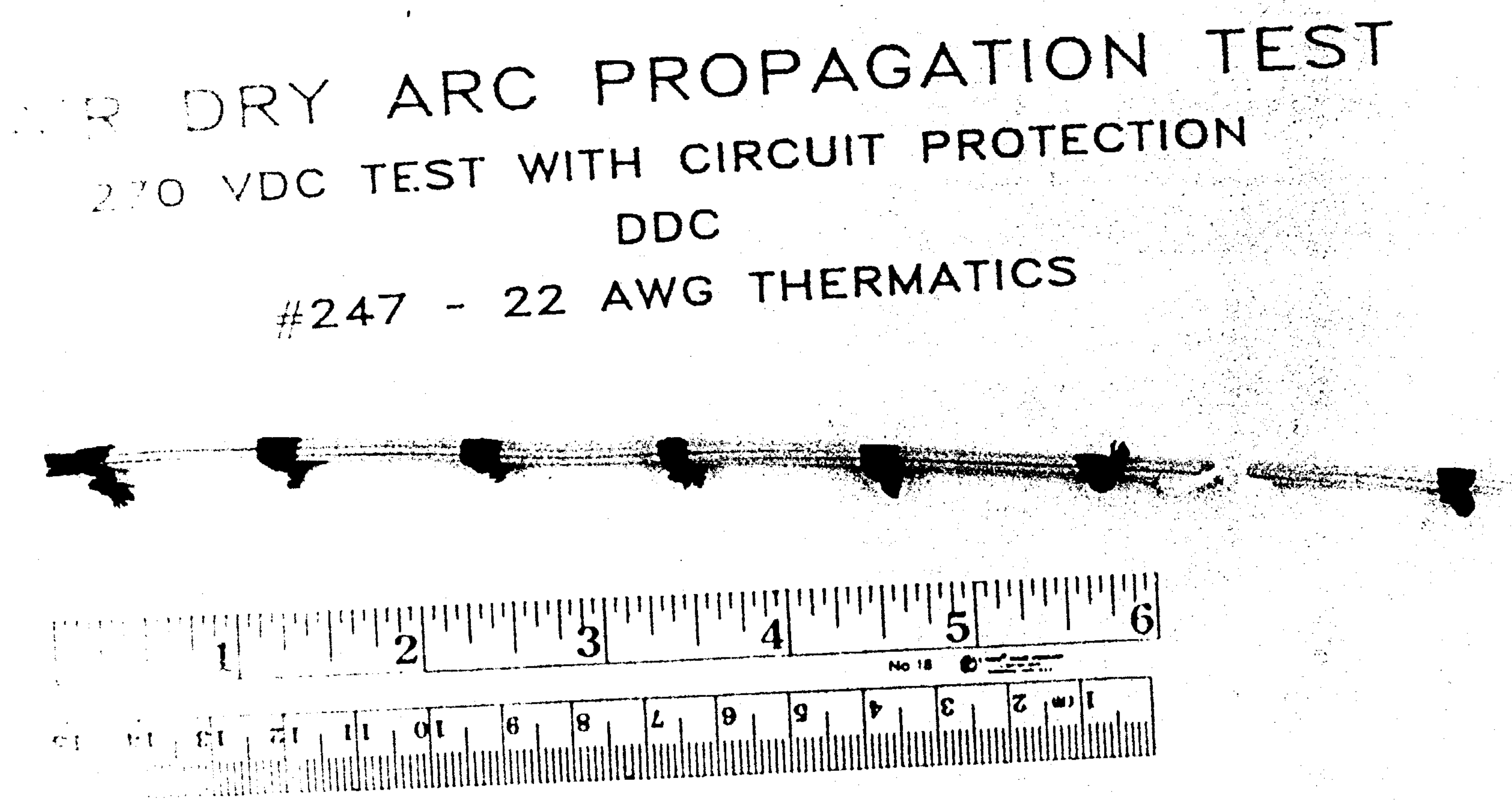


FIGURE H15 - THERMATICS (#247) HARNESS TESTED WITH ILC DATA DEVICE CORPORATION POWER CONTROLLERS

·RY ARC PROPAGATION TEST

.DC TEST WITH CIRCUIT PROTECTION

DDC

#257 - 22 AWG NEMA #3

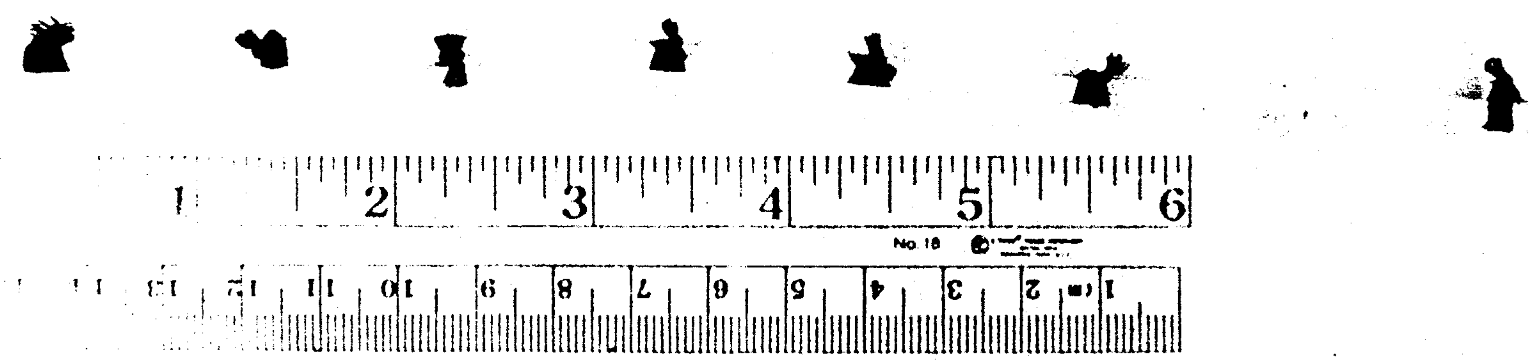


FIGURE H16 - NEMA #3 (#257) HARNESS TESTED WITH ILC DATA DEVICE CORPORATION POWER CONTROLLERS

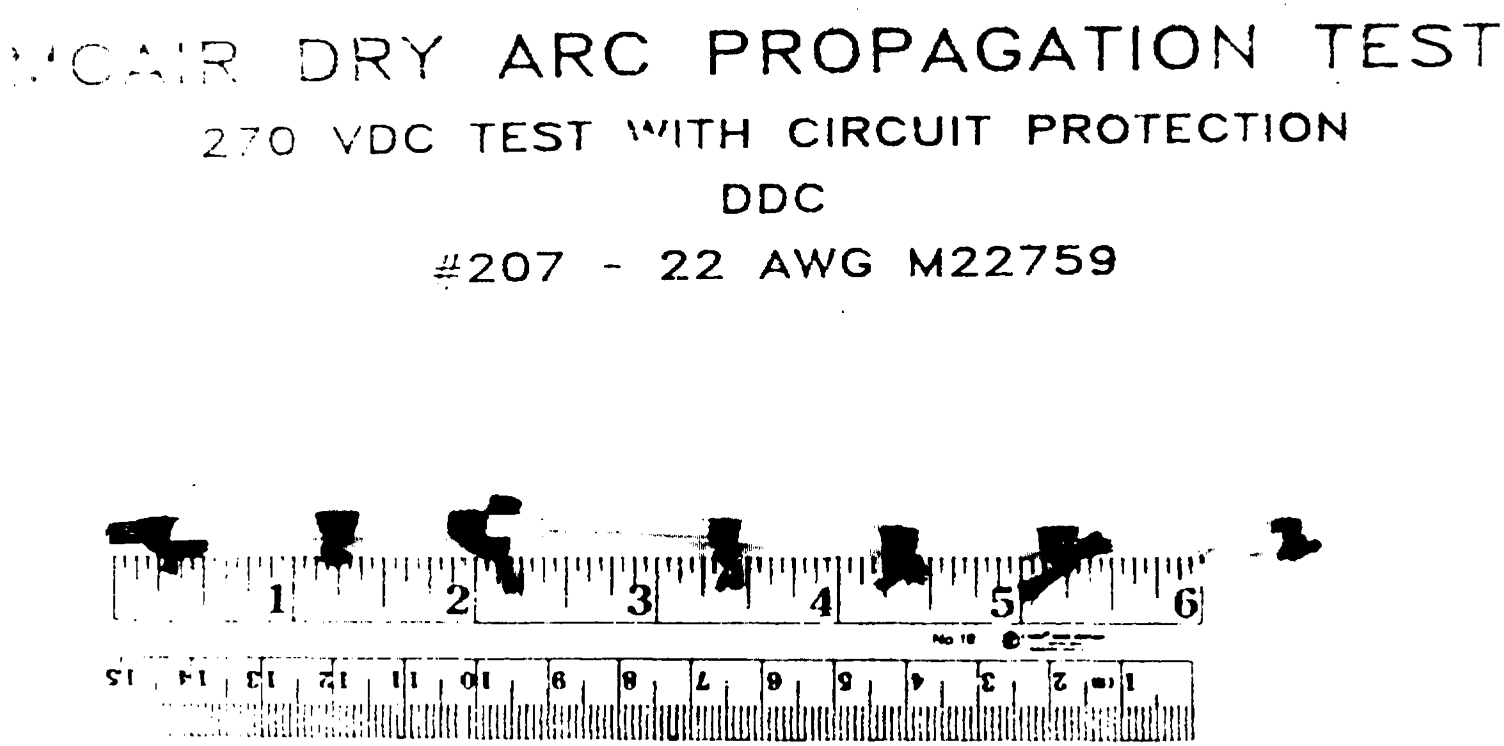


FIGURE H17 - M22759 (#207) HARNESS TESTED WITH ILC DATA DEVICE CORPORATION POWER CONTROLLERS

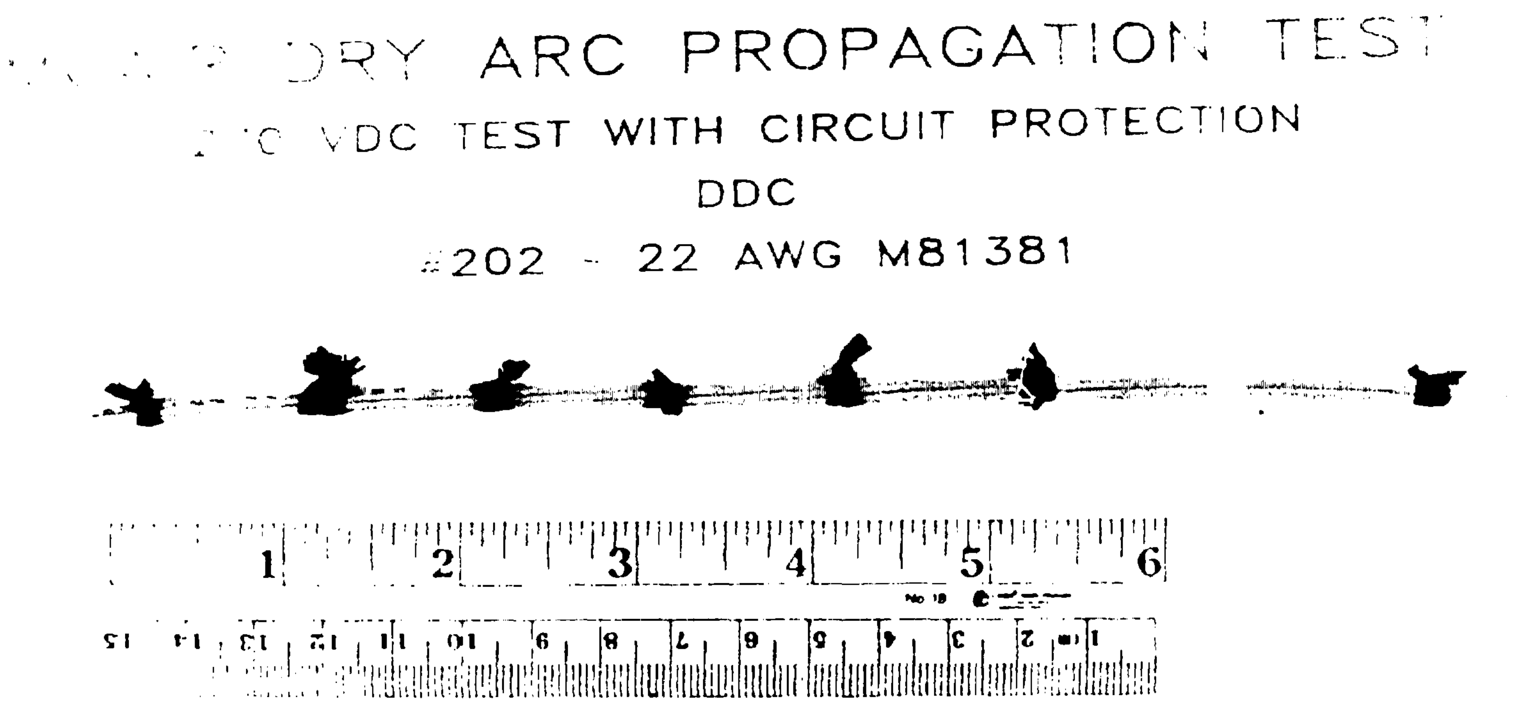


FIGURE H18 - M81381 (#202) HARNESS TESTED WITH ILC DATA DEVICE CORPORATION POWER CONTROLLERS

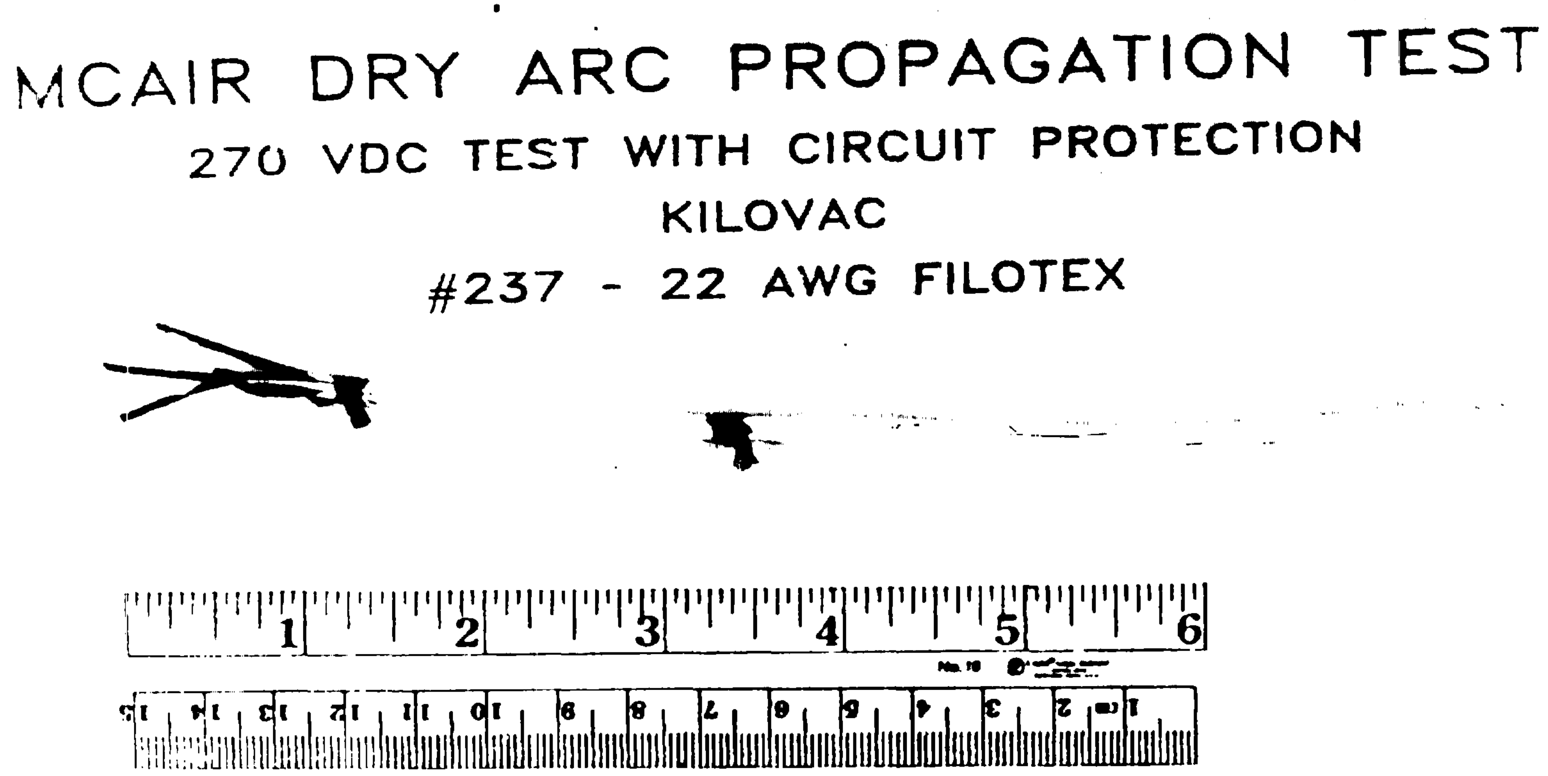


FIGURE H19 -- FILOTEX (#237) HARNESS TESTED WITH KILOVAC POWER CONTROLLERS

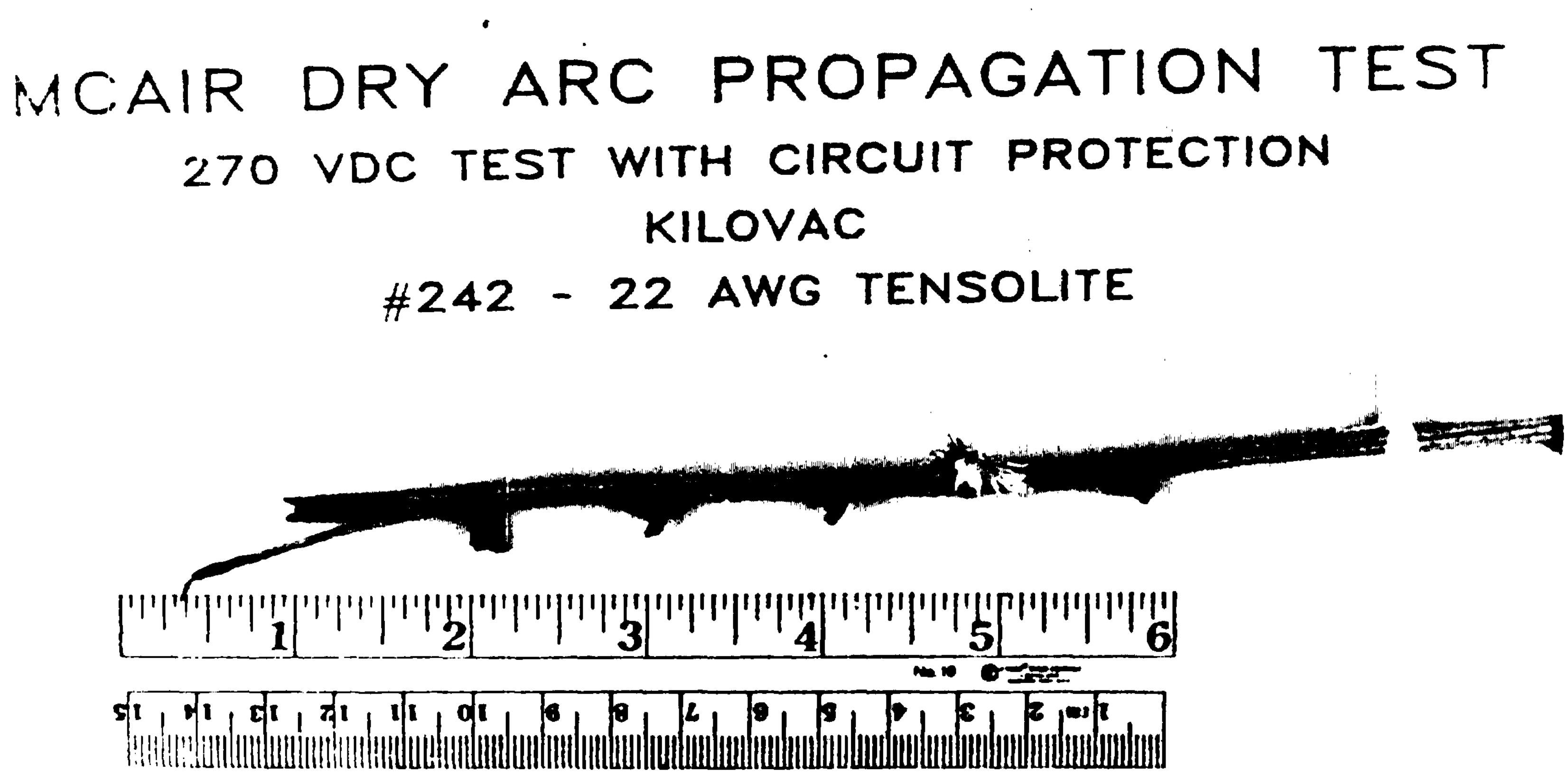


FIGURE H20 - TENSOLITE (#242) HARNESS TESTED WITH KILOVAC POWER CONTROLLERS

MCAIR DRY ARC PROPAGATION TEST

270 VDC TEST WITH CIRCUIT PROTECTION

KILOVAC

#247 - 22 AWG THERMATICS

FIGURE H21 - THERMATICS (#247) HARNESS TESTED WITH KILOVAC POWER CONTROLLERS

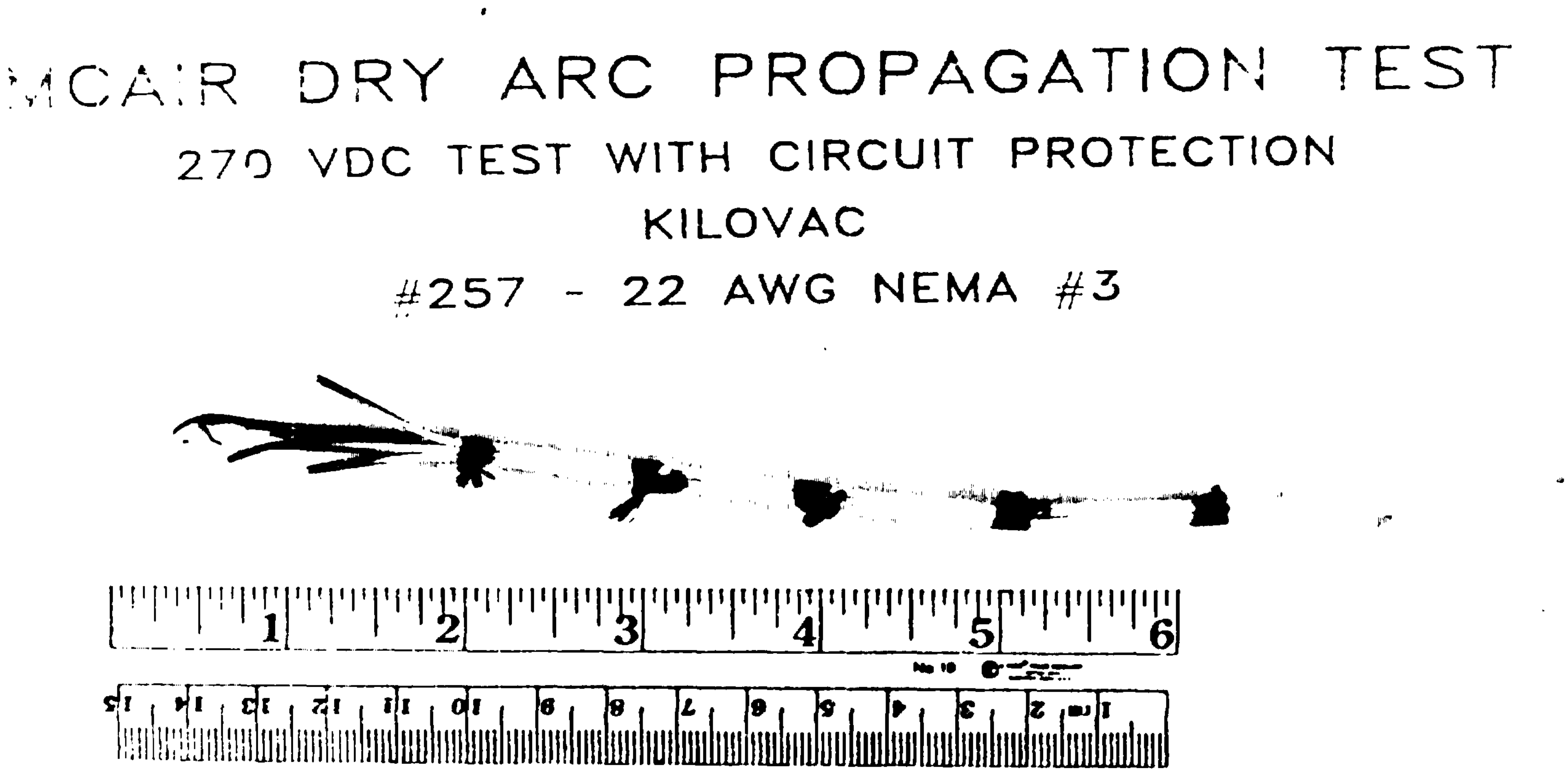


FIGURE H22 - NEMA #3 (#257) HARNESS TESTED WITH KILOVAC POWER CONTROLLERS

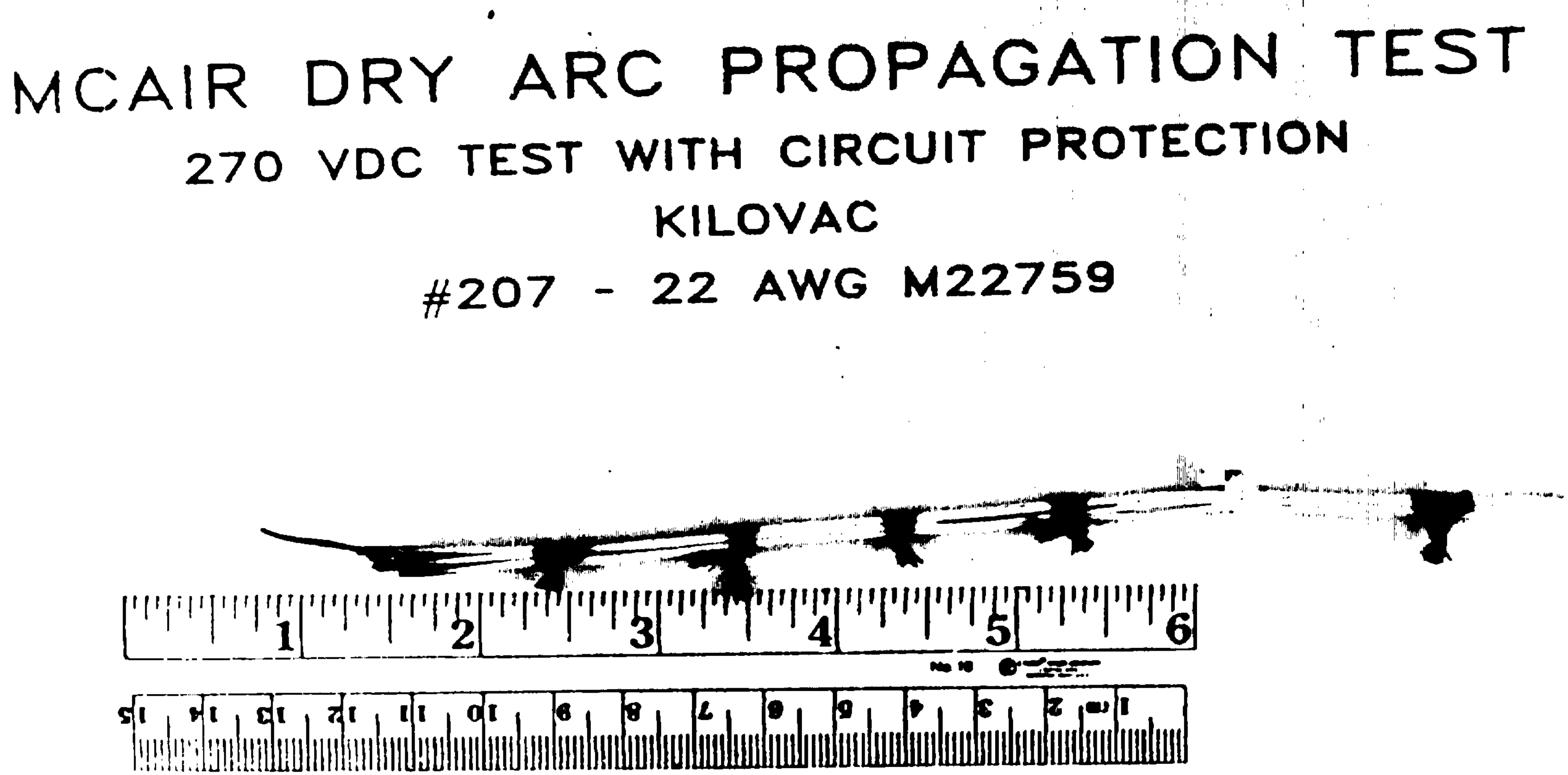


FIGURE H23 - M22759 (#207) HARNESS TESTED WITH KILOVAC POWER CONTROLLERS

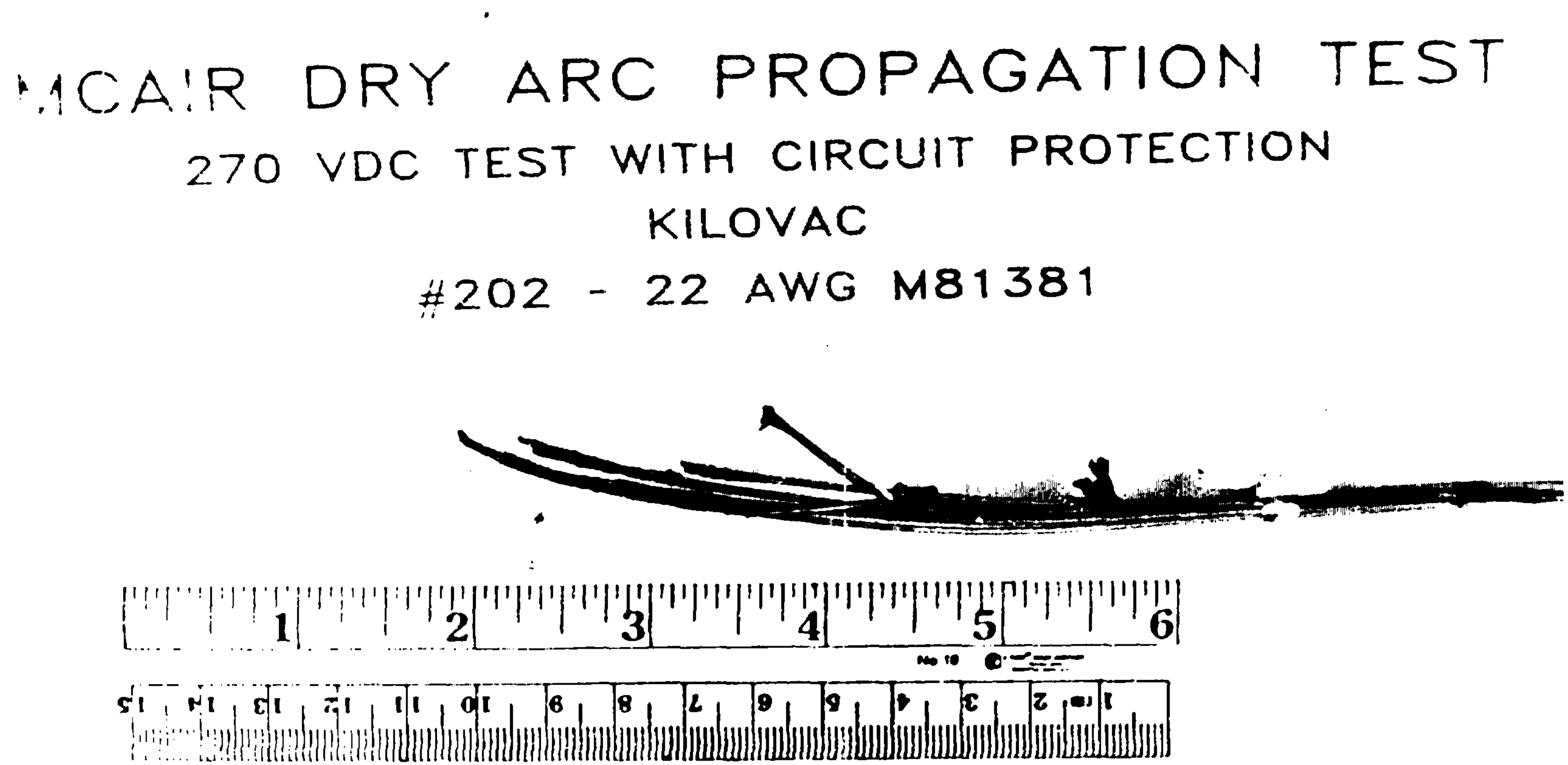


FIGURE H24 - M81381 (#202) HARNESS TESTED WITH KILOVAC POWER CONTROLLERS

MCAIR DRY ARC PROPAGATION TEST

270 VDC TEST WITH CIRCUIT PROTECTION

EATON

#236 - 12 AWG FILOTEX

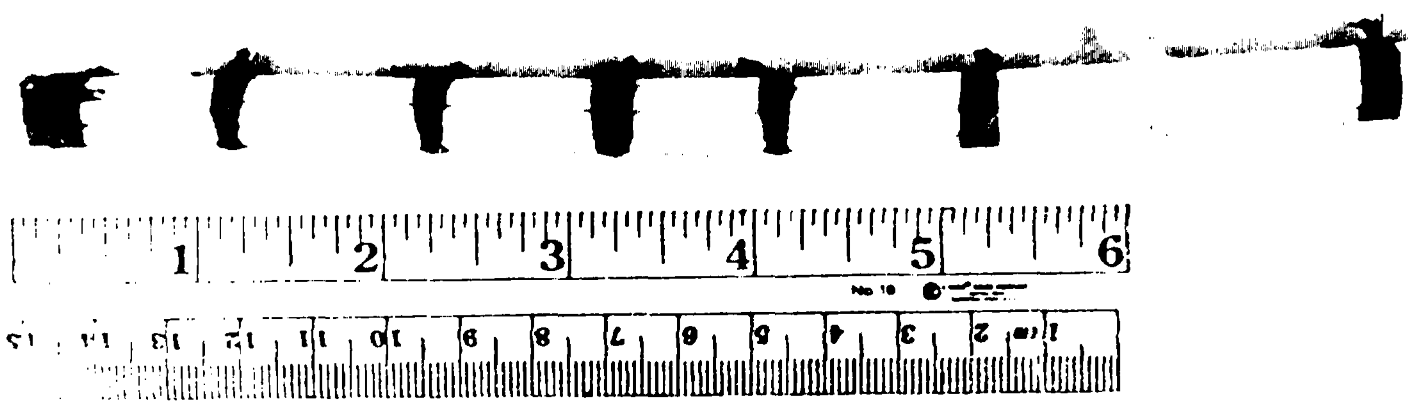


FIGURE H25 - FILOTEX (#236) HARNESS TESTED WITH EATON POWER CONTROLLERS

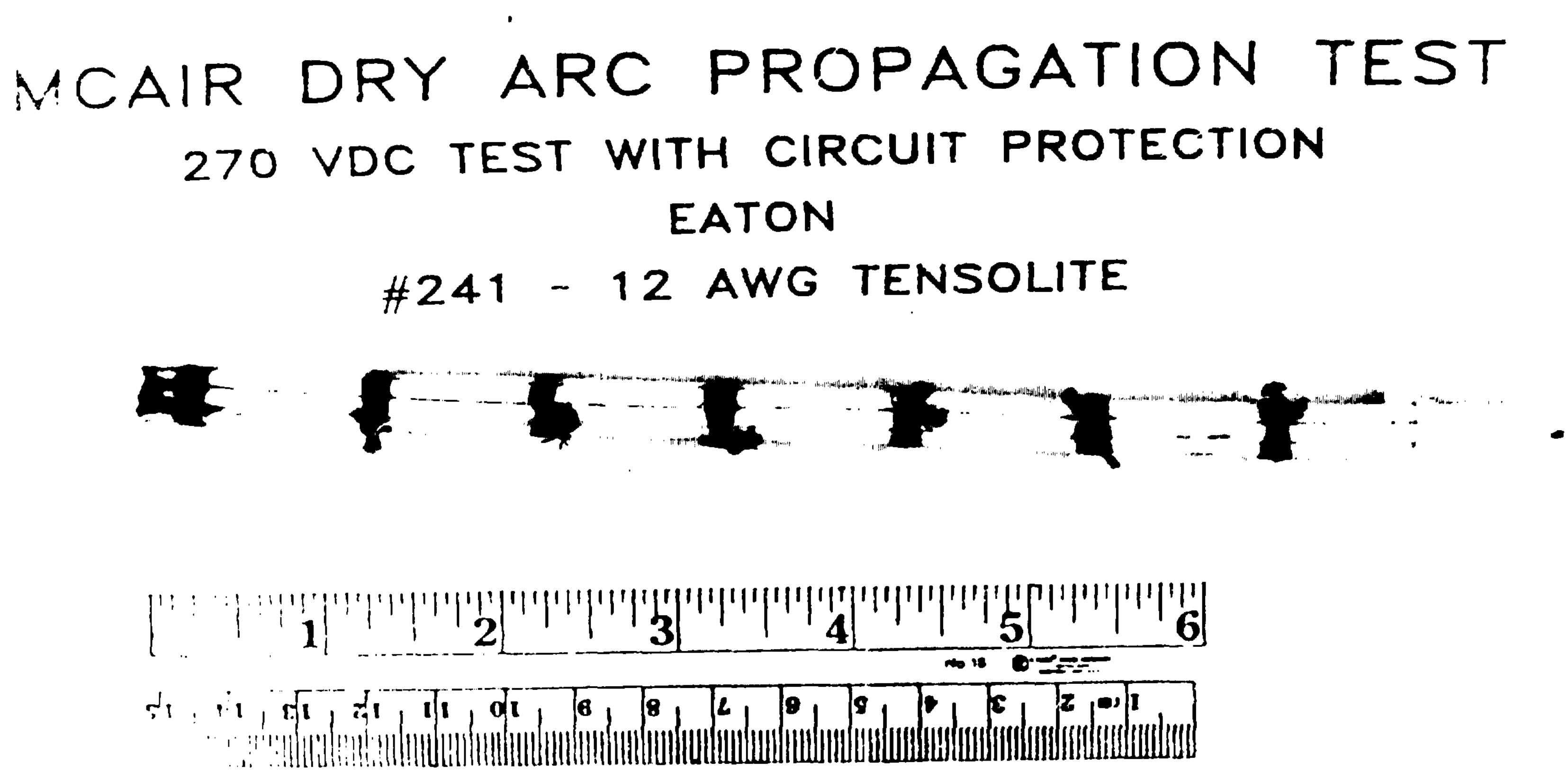


FIGURE H26 - TENSOLITE (#241) HARNESS TESTED WITH EATON POWER CONTROLLERS

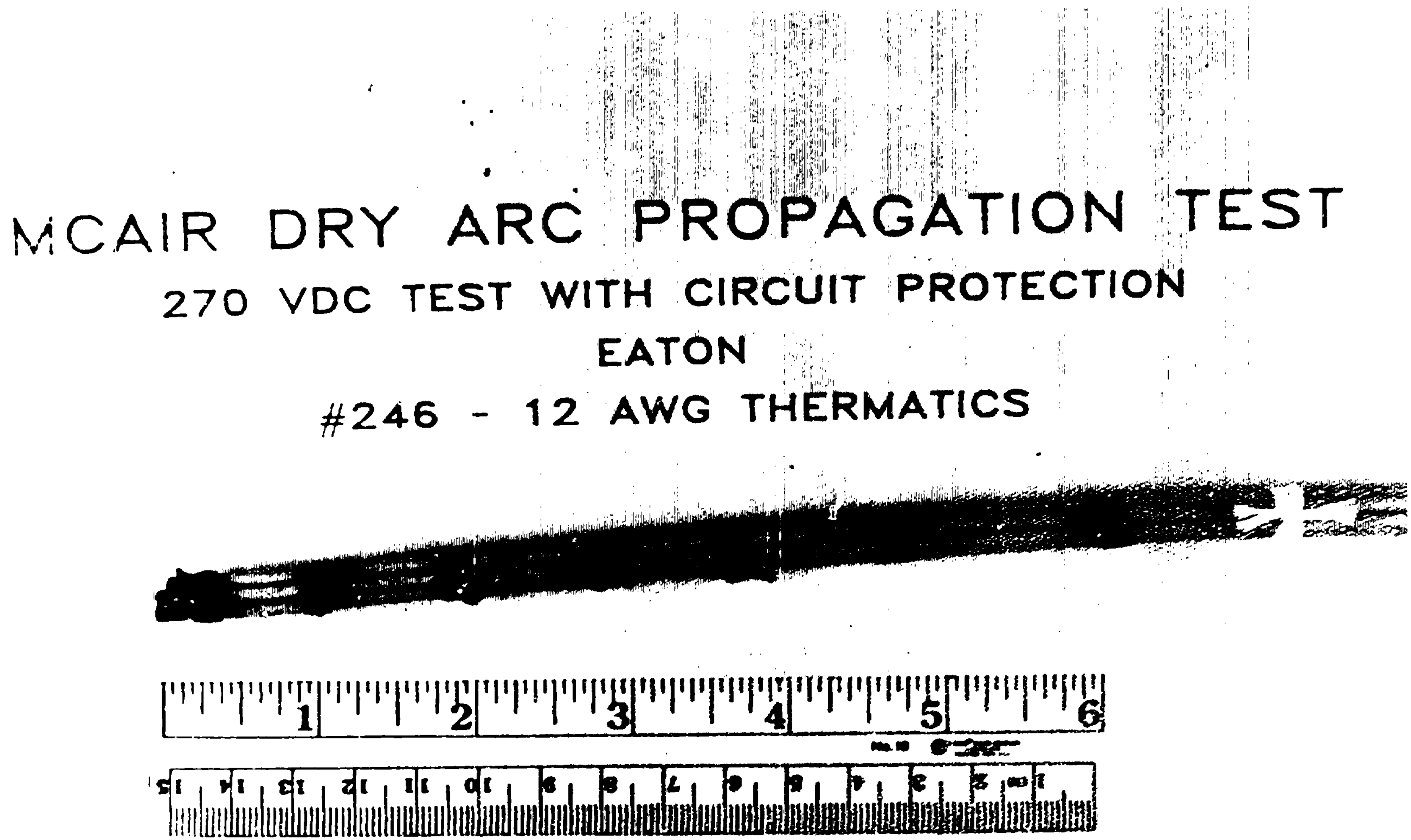


FIGURE H27 - THERMATICS (#246) HARNESS TESTED WITH EATON POWER CONTROLLERS

MCAIR DRY ARC PROPAGATION TEST

270 VDC TEST WITH CIRCUIT PROTECTION

EATON

#256 - 12 AWG NEMA #3

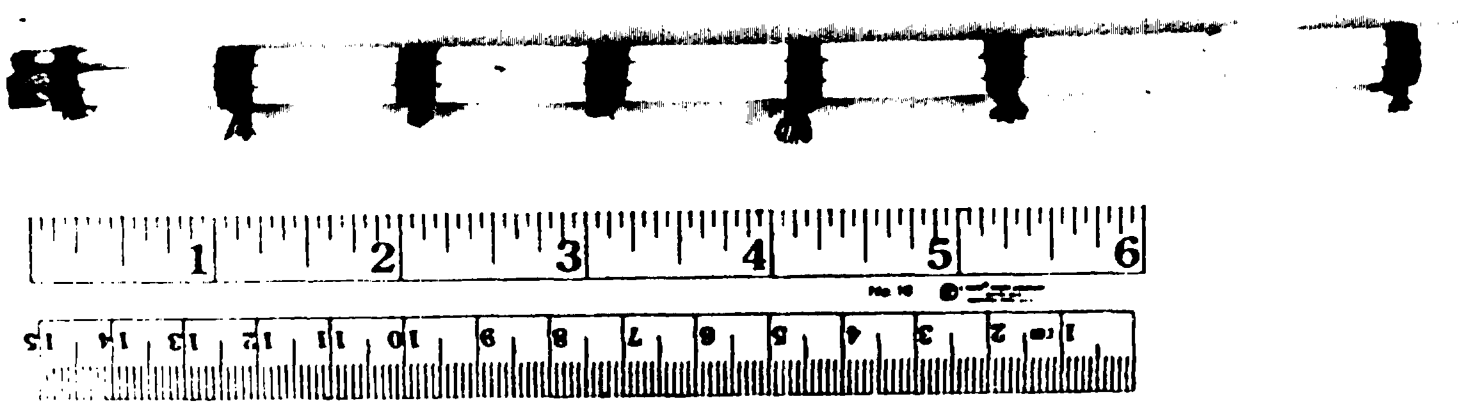


FIGURE H28 - NEMA #3 (#256) HARNESS TESTED WITH EATON POWER CONTROLLERS

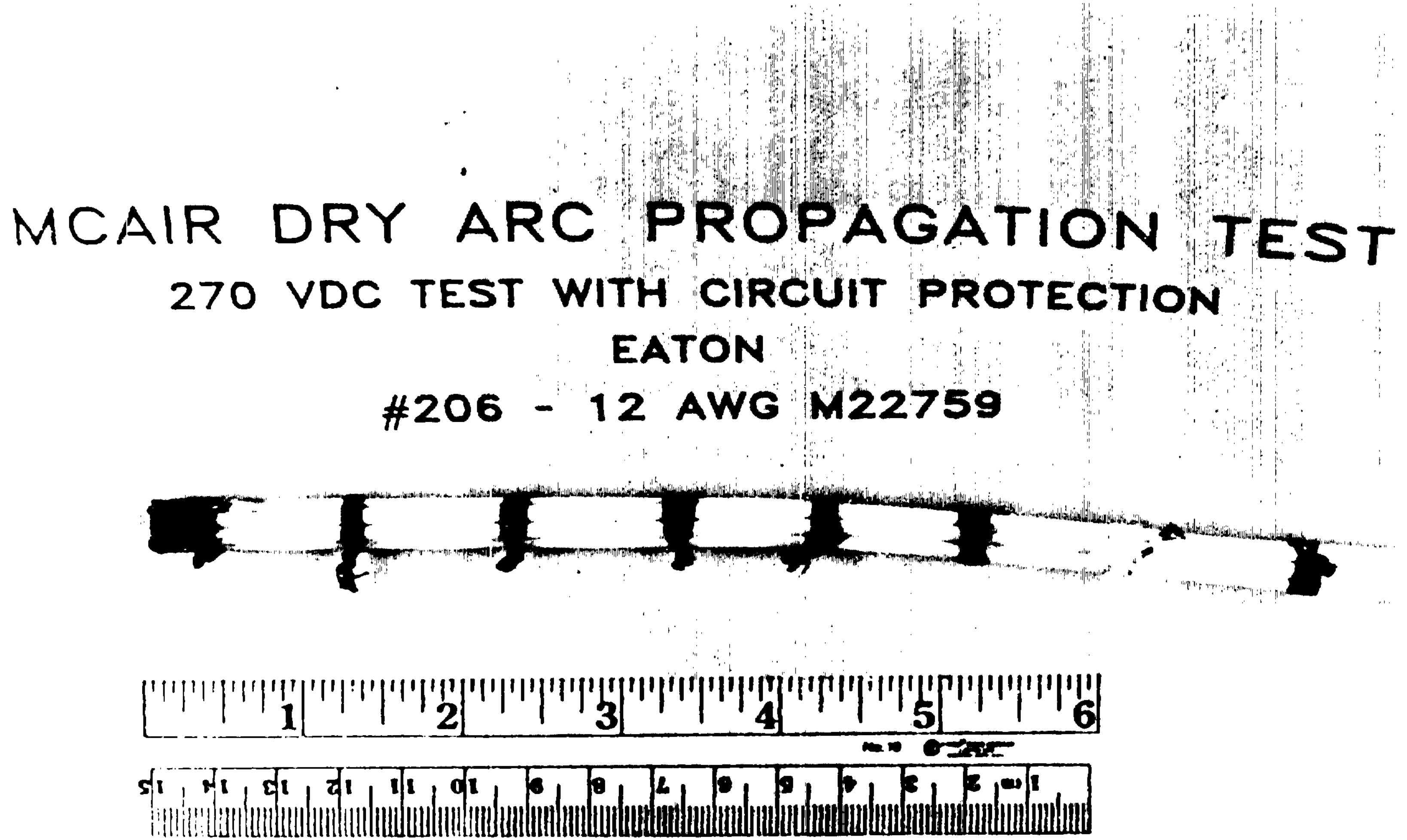


FIGURE H29 - M22759 (#206) HARNESS TESTED WITH EATON POWER CONTROLLERS

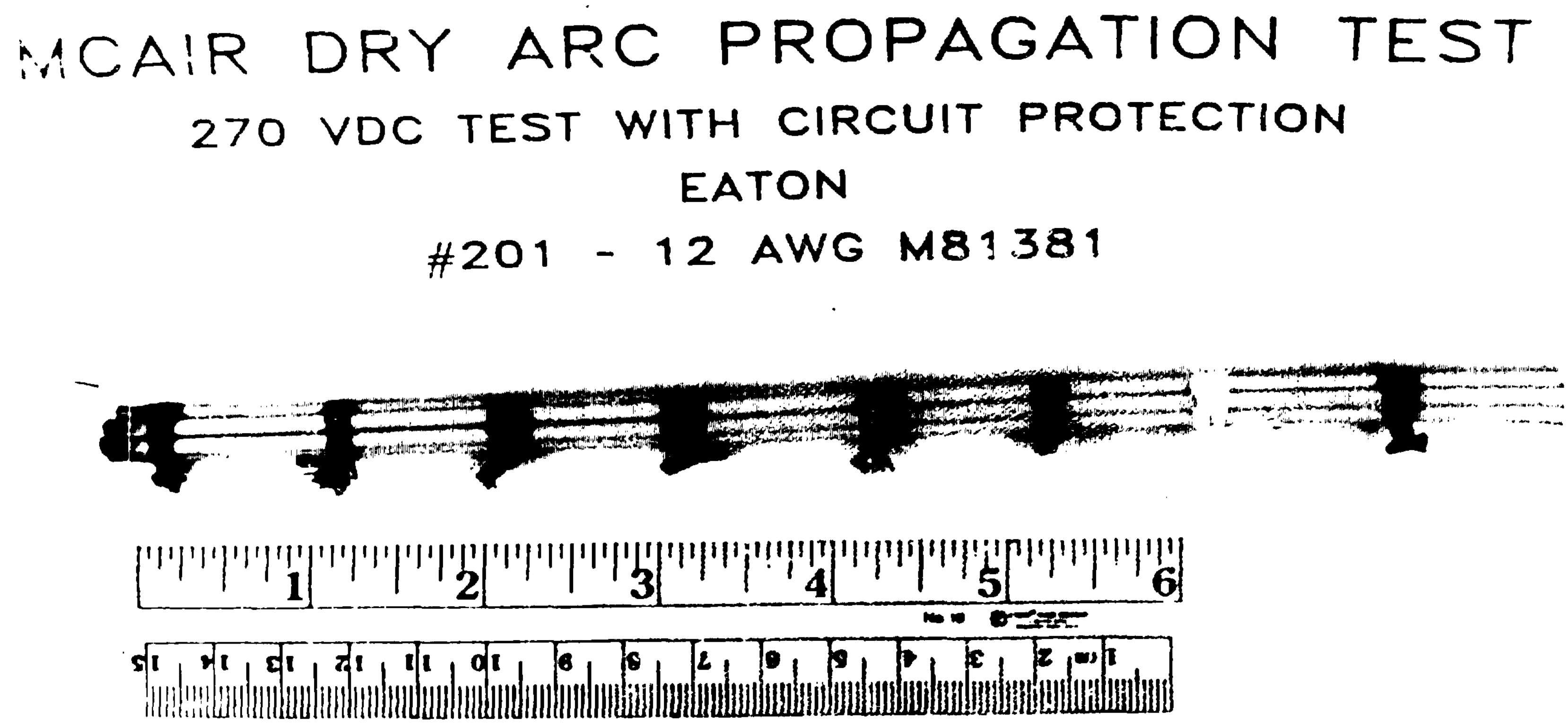


FIGURE H30 - M81381 (#201) HARNESS TESTED WITH EATON POWER CONTROLLERS

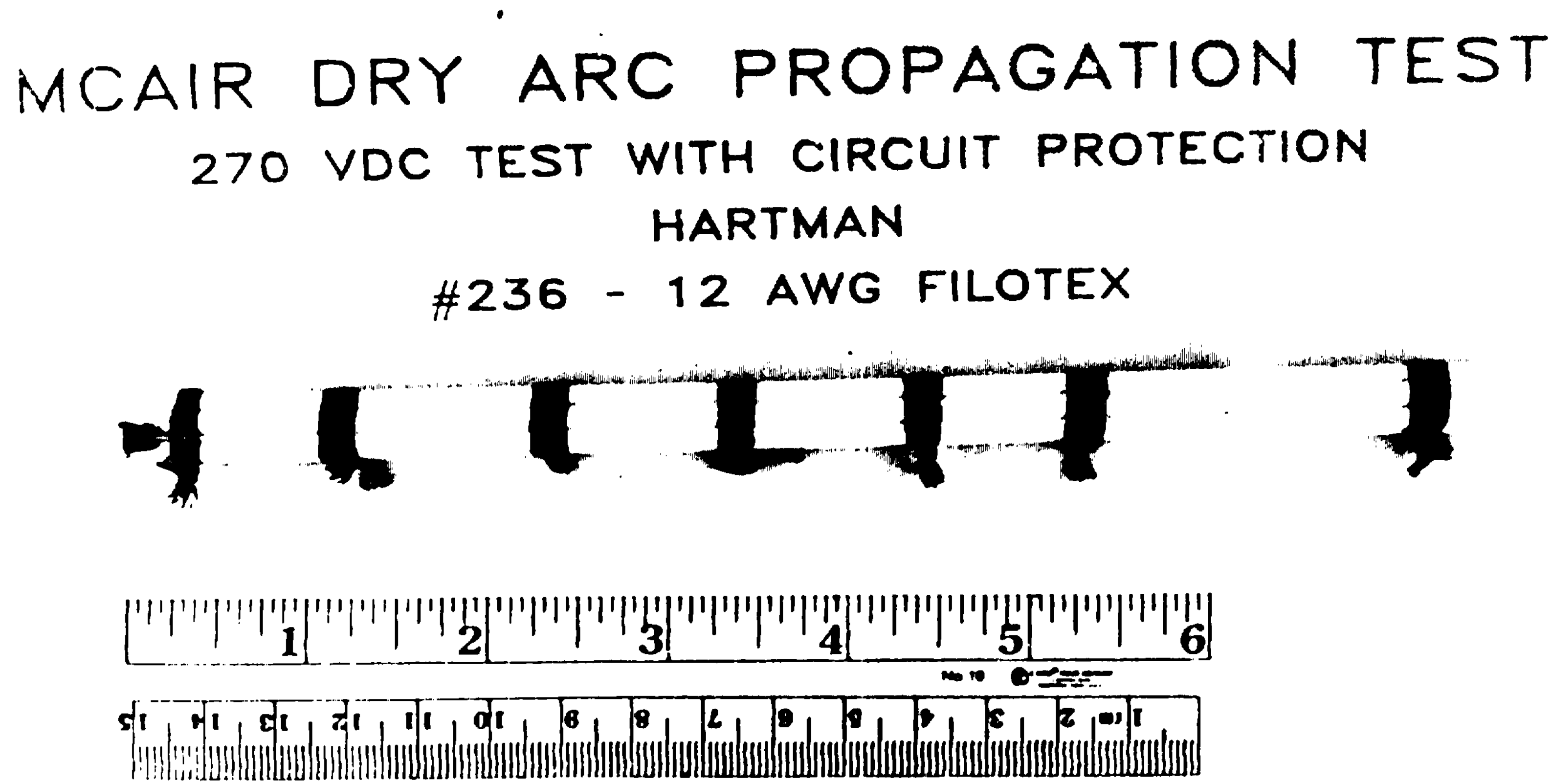


FIGURE H31 - FILOTEX (#236) HARNESS TESTED WITH HARTMAN POWER CONTROLLERS

MCAIR DRY ARC PROPAGATION TEST

270 VDC TEST WITH CIRCUIT PROTECTION

HARTMAN

#241 - 12 AWG TENSOLITE

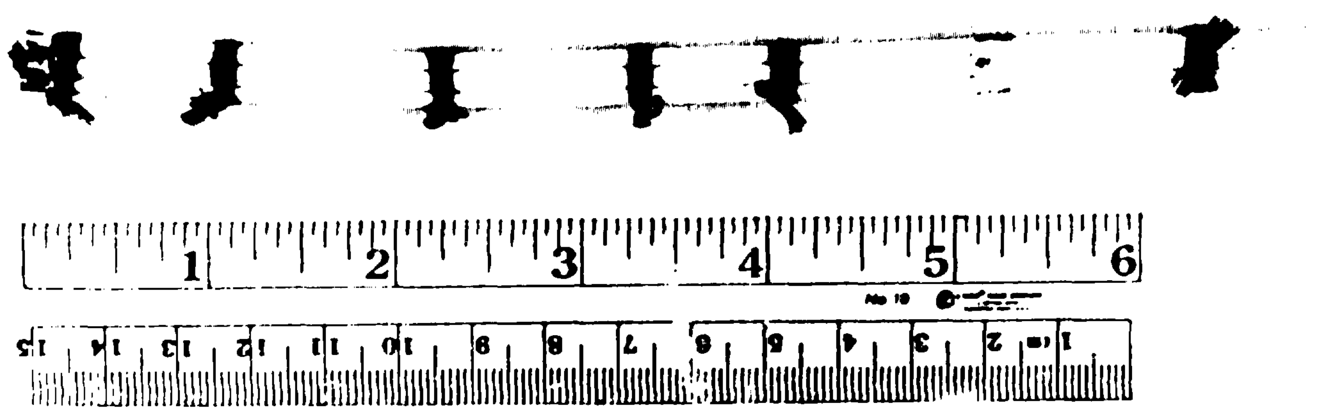


FIGURE H32 - TENSOLITE (#241) HARNESS TESTED WITH HARTMAN POWER CONTROLLERS

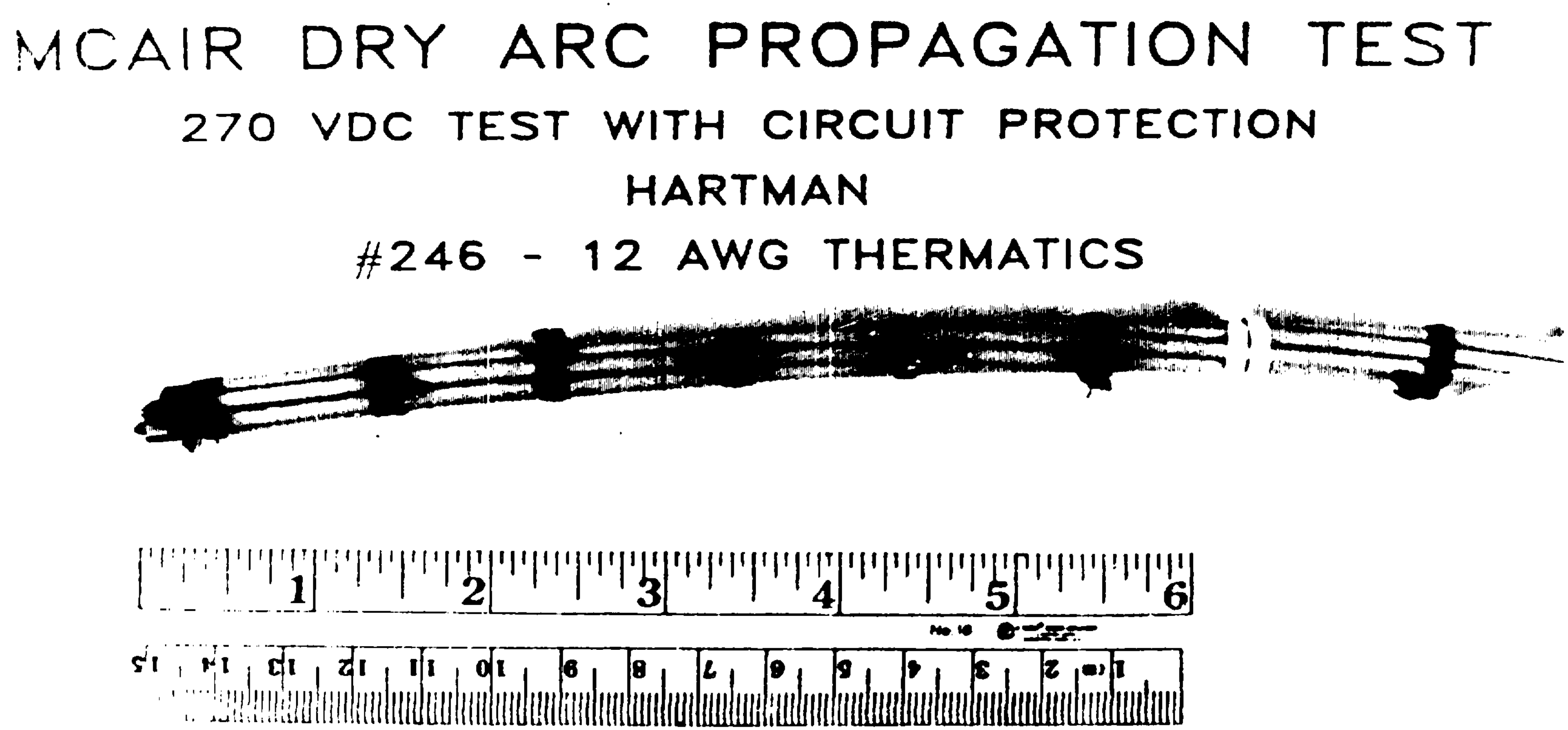


FIGURE H33 - THERMATICS (#246) HARNESS TESTED WITH HARTMAN POWER CONTROLLERS

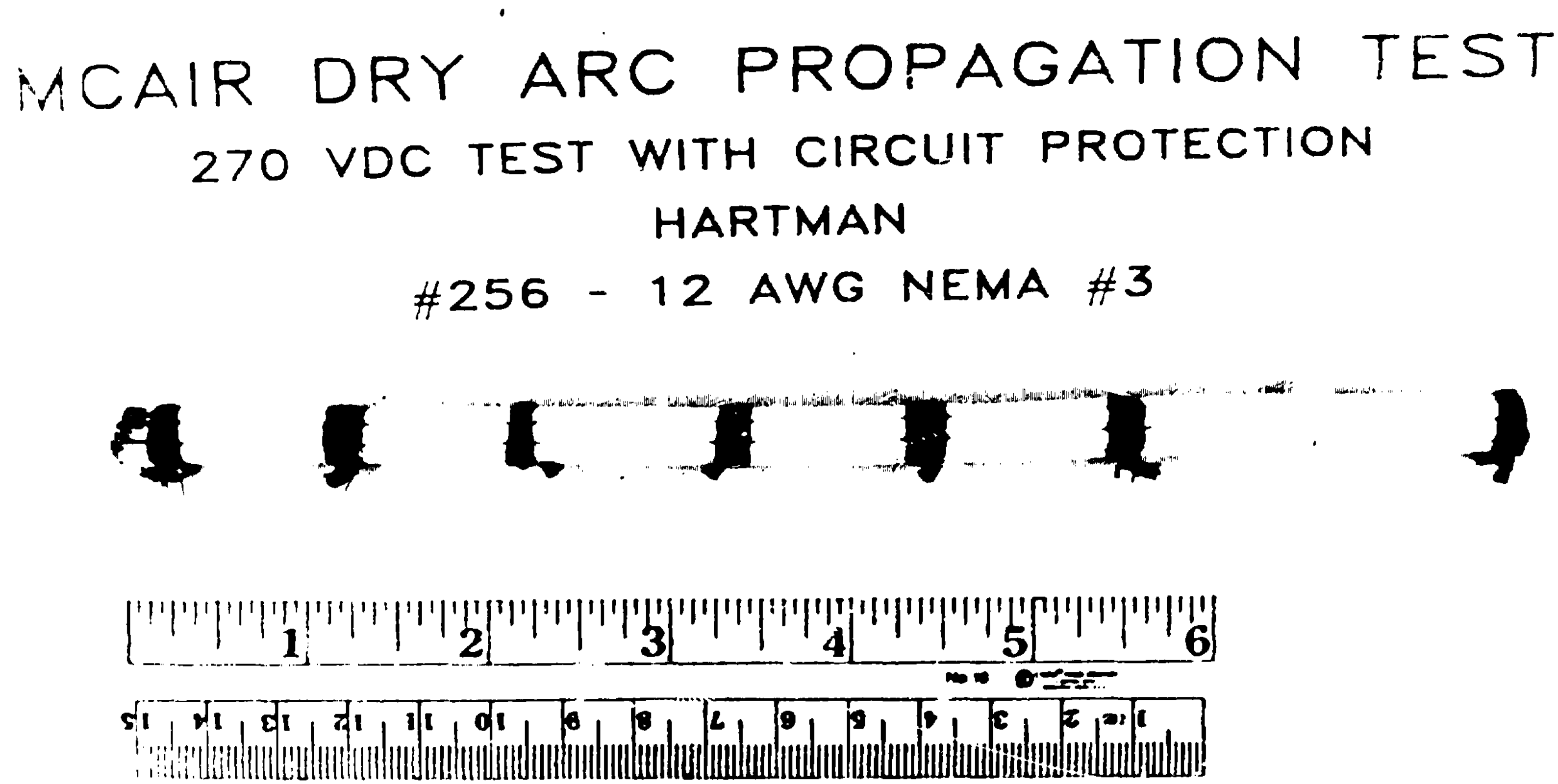


FIGURE H34 - NEMA #3 (#256) HARNESS TESTED WITH HARTMAN POWER CONTROLLERS

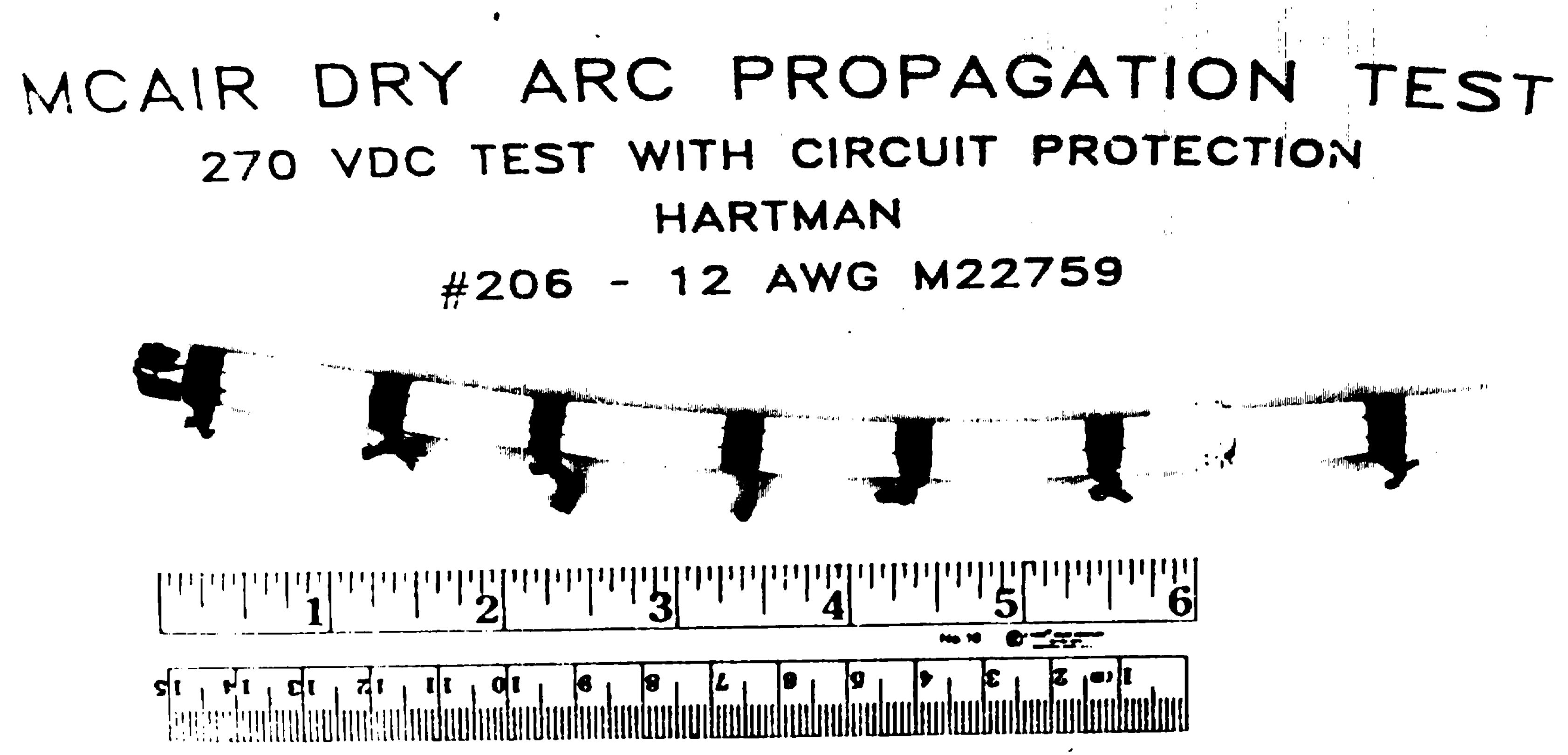


FIGURE H35 - M22759 (#206) HARNESS TESTED WITH HARTMAN POWER CONTROLLERS

MCAIR DRY ARC PROPAGATION TEST

270 VDC TEST WITH CIRCUIT PROTECTION

HARTMAN

#201 - 12 AWG M81381

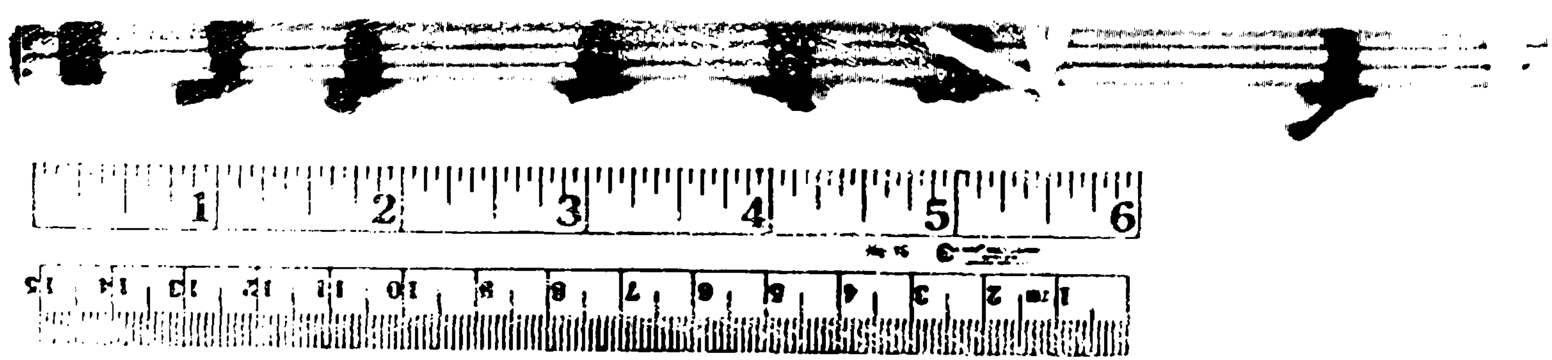


FIGURE H36 - M81381 (#201) HARNESS TESTED WITH HARTMAN POWER CONTROLLERS

APPENDIX I

RESULTS OF POWER CONTROLLER FUNCTIONAL TESTS

Inclusive pages: 184 - 201

TABLE I1 - FUNCTIONAL TEST RESULTS OF TELEDYNE SOLID STATE POWER CONTROLLER #1

POWER CONTROLLER RATED AT 5 AMPS

SSPC #1 = FSCM63745 VD46KKW (9020-17B)

POST HARNESS NUMBER CHECKOUT	TURN-ON TIME (100% LOAD) MIL-R-28750B	TURN-OFF TIME (100% LOAD) MIL-R-28750B	VOLTAGE DROP (100% LOAD) MIL-R-28750B	TRIP TIME (300% LOAD) MIL-R-28750B	TRIP TIME CURRENT DURATION (300% LOAD)
INIT. CHECKOUT	116 µs	564 µs	0.4880 V	601.60 ms	602.88 ms
FILOTEX #237	116 µs	562 µs	0.4820 V	592.64 ms	593.92 ms
TENSOLITE #242	112 µs	558 µs	0.4870 V	596.24 ms	596.48 ms
THERMATICS #247	114 µs	564 µs	0.4780 V	598.80 ms	599.04 ms
NEMA 3 #257	111 µs	560 µs	0.4840 V	597.44 ms	597.77 ms
M22759 #207	126 µs	80 µs	0.4560 V	599.04 ms	599.26 ms
M81381 #202	127 µs	582 µs	0.4640 V	609.28 ms	615.68 ms

TABLE 12 - FUNCTIONAL TEST RESULTS OF TELEDYNE SOLID STATE POWER CONTROLLER #2

POWER CONTROLLER RATED AT 5 AMPS

SSPC #2 = FSCM63745 VD46KKW (9020-17C)

POST HARNESS NUMBER CHECKOUT	TURN-ON TIME (100% LOAD) MIL-R-22750B	TURN-OFF TIME (100% LOAD) MIL-R-22750B	VOLTAGE DROP (100% LOAD) MIL-R-22750B	TRIP TIME (300% LOAD) MIL-R-22750B	TRIP TIME CURRENT DURATION (300% LOAD)
INIT. CHECKOUT	109 µs	588 µs	0.4650 V	4.20 ms	4.52 ms
FILOTEX #237	109 µs	588 µs	0.4720 V	4.20 ms	4.52 ms
TENSOLITE #242	107 µs	586 µs	0.4700 V	4.52 ms	4.68 ms
THERMATICS #247	110 µs	586 µs	0.4670 V	4.36 ms	4.56 ms
NEMA 3 #257	111 µs	588 µs	0.4700 V	4.47 ms	4.75 ms
M22759 #207	120 µs	604 µs	0.4460 V	4.20 ms	4.46 ms
M81381 #202	126 µs	604 µs	0.4530 V	4.16 ms	4.43 ms

TABLE 13 - FUNCTIONAL TEST RESULTS OF TELEDYNE SOLID STATF POWER CONTROLLER #3

POWER CONTROLLER RATED AT 5 AMPS

SSPC #3 - FSCM63745 VD46KKW (9020-17C)

POST HARNESS NUMBER CHECKOUT	TURN-ON TIME (100% LOAD) MIL-R-22750B	TURN-OFF TIME (100% LOAD) MIL-R-22750B	VOLTAGE DROP (100% LOAD) MIL-R-22750B	TRIP TIME (300% LOAD) MIL-R-22750B	TRIP TIME CURRENT DURATION (300% LOAD)
INIT. CHECKOUT	111 μs	588 μs	0.4688 V	647.68 ms	650.24 ms
FILOTEX #237	114 μs	586 μs	0.4630 V	642.56 ms	642.56 ms
TENSOLITE #242	113 μs	586 μs	0.4620 V	644.88 ms	645.12 ms
THERMATICS #247	112 μs	588 μs	0.4630 V	647.40 ms	647.68 ms
NEMA 3 #257	113 μs	592 μs	0.4620 V	648.96 ms	649.31 ms
M22759 #207	128 μs	604 μs	0.4370 V	645.12 ms	647.68 ms
M81381 #202	130 μs	602 μs	0.4470 V	657.92 ms	663.04 ms

TABLE 14 - FUNCTIONAL TEST RESULTS OF TEXAS INSTRUMENTS POWER CONTROLLER #1

POWER CONTROLLER RATED AT 10 AMPS

SSPC #1 - EX 3407-100-10 (270-007-10)

POST HARNESS NUMBER CHECKOUT	TURN-ON TIME (100% LOAD) MIL-P-81653C	TURN-OFF TIME (100% LOAD) MIL-P-81653C	VOLTAGE DROP (100% LOAD) MIL-P-81653C	PEAK LET-THROUGH CURRENT (SHORT) MIL-P-81653C	CURRENT LIMIT LEVEL (SHORT) MIL-P-81653C	TRIP TIME (300% LOAD) MIL-P-81653C
INIT. CHECKOUT	174 μs	730 μs	0.8599 V	78.6 A	39.6 A	2.611 s
F[illegible]CTEX #237	136 μs	710 μs	0.7756 V	79.2 A	38.8 A	2.470 s
TENSOLITE #242	136 μs	700 μs	0.7890 V	79.2 A	37.6 A	2.573 s
THERMATICS #247	133 μs	696 μs	0.7830 V	78.4 A	36.8 A	2.528 s
NEMA 3 #257	133 μs	696 μs	0.7860 V	77.6 A	36.8 A	2.592 s
M22759 #207	140 μs	720 μs	0.8100 V	91.2 A	40.0 A	1.498 s
M81381 #202	152 μs	698 μs	0.7570 V	86.4 A	37.6 A	2.657 s

TABLE 15 - FUNCTIONAL TEST RESULTS OF TEXAS INSTRUMENTS POWER CONTROLLER #2

POWER CONTROLLER RATED AT 10 AMPS

SSPC #2 = EX 3407-100-10 (270-006-10)

POST HARNESS NUMBER CHECKOUT	TURN-ON TIME (100% LOAD) MIL-P-81653C	TURN-OFF TIME (100% LOAD) MIL-P-81653C	VOLTAGE DROP (100% LOAD) MIL-P-81653C	PEAK LET-THROUGH CURRENT (SHORT) MIL-P-81653C	CURRENT LIMIT LEVEL (SHORT) MIL-P-81653C	TRIP TIME (300% LOAD) MIL-P-81653C
INIT. CHECKOUT	182 μs	1000 μs	0.8500 V	78.6 A	40.8 A	2.483 s
FILOTEX #237	144 μs	968 μs	0.7870 V	80.0 A	39.2 A	2.387 s
TENSOLITE #242	143 μs	968 μs	0.7350 V	80.0 A	38.4 A	2.464 s
THERMATICS #247	141 μs	964 μs	0.7650 V	79.2 A	36.8 A	2.400 s
NEMA 3 #257	142 μs	964 μs	0.7516 V	77.6 A	36.0 A	2.464 s
M22759 #207	160 μs	985 μs	0.7700 V	92.8 A	40.0 A	1.546 s
M81381 #202	148 μs	968 μs	0.7330 V	88.8 A	37.6 A	2.496 s

TABLE 16 - FUNCTIONAL TEST RESULTS OF TEXAS INSTRUMENTS POWER CONTROLLER #3

POWER CONTROLLER RATED AT 10 AMPS

SSPC #3 = EX 3407-100-10 (270-005-10)

TEST HARNESS NUMBER CHECKOUT	TURN-ON TIME (100% LOAD) MIL-P-81653C	TURN-OFF TIME (100% LOAD) MIL-P-81653C	VOLTAGE DROP (100% LOAD) MIL-P-81653C	PEAK LET-THROUGH CURRENT (SHORT) MIL-P-81653C	CURRENT LIMIT LEVEL (SHORT) MIL-P-81653C	TRIP TIME (300% LOAD) MIL-P-81653C
INIT. CHECKOUT	172 μs	1064 μs	0.9250 V	80.6 A	39.8 A	2.675 s
FILOTEX #237	135 μs	1002 μs	0.7612 V	80.8 A	39.2 A	2.656 s
TENSOLITE #242	134 μs	1024 μs	0.7724 V	80.0 A	38.4 A	2.630 s
THERMATICS #247	133 μs	1016 μs	0.7660 V	79.2 A	36.0 A	2.669 s
NEMA 3 #257	132 μs	1020 μs	0.7777 V	79.2 A	36.0 A	2.624 s
M22759 #207	150 μs	1040 μs	0.7800 V	89.6 A	40.0 A	1.823 s
M81381 #202	139 μs	1024 μs	0.7440 V	88.0 A	38.4 A	2.718 s

TABLE 17 - FUNCTIONAL TEST RESULTS OF ILC DATA DEVICE CORP. POWER CONTROLLER #1

POWER CONTROLLER RATED AT 15 AMPS

SSPC #1 = 19645 SSP 21116-015 9046 (S/N 008)

POST HARNESS NUMBER CHECKOUT	TURN-ON TIME (100% LOAD) MIL-P-81653C	TURN-OFF TIME (100% LOAD) MIL-P-81653C	VOLTAGE DROP (100% LOAD) MIL-P-81653C	TRIP TIME (300% LOAD) MIL-P-81653C	TRIP TIME CURRENT DURATION (300% LOAD)
INIT. CHECKOUT	776 μs	688 μs	0.8020 V	[1]	652.80 ms
FILOTEX #237	1016 μs	736 μs	0.7300 V	[1]	263.20 ms
TENSOLITE #242	816 μs	768 μs	0.7150 V	[1]	261.60 ms
THERMATICS #247	884 μs	756 μs	0.7110 V	[1]	264.80 ms
NEMA 3 #257	816 μs	752 μs	0.7180 V	[1]	264.32 ms
M22759 #207	824 μs	756 μs	0.7190 V	[1]	264.96 ms
M81381 #202	812 μs	740 μs	0.7400 V	[1]	263.68 ms

[1] - TRIP TIME DATA NOT ACQUIRED BECAUSE THE STATUS AND TRIP SIGNALS WERE NOT FUNCTIONING PROPERLY.

TABLE 18 - FUNCTIONAL TEST RESULTS OF ILC DATA DEVICE CORP. POWER CONTROLLER #2

POWER CONTROLLER RATED AT 15 AMPS

SSPC #2 = 19645 SSP 21116-015 9046 (S/N 009)

POST HARNESS NUMBER CHECKOUT	TURN-ON TIME (100% LOAD) MIL-P-81653C	TURN-OFF TIME (100% LOAD) MIL-P-81653C	VOLTAGE DROP (100% LOAD) MIL-P-81653C	TRIP TIME (300% LOAD) MIL-P-81653C	TRIP TIME CURRENT DURATION (300% LOAD)
INIT. CHECKOUT	760 μs	720 μs	0.7828 V	[1]	598.40 ms
FILOTEX #237	768 μs	712 μs	0.7030 V	[1]	243.20 ms
TENSOLITE #242	776 μs	720 μs	0.7140 V	[1]	243.20 ms
THERMATICS #247	772 μs	708 μs	0.6890 V	[1]	244.00 ms
NEMA 3 #257	768 μs	704 μs	0.7120 V	[1]	244.48 ms
M22759 #207	764 μs	716 μs	0.7070 V	[1]	244.48 ms
M81381 #202	768 μs	732 μs	0.7270 V	[1]	244.48 ms

[1] - TRIP TIME DATA NOT ACQUIRED BECAUSE THE STATUS AND TRIP SIGNALS WERE NOT FUNCTIONING PROPERLY.

TABLE 19 - FUNCTIONAL TEST RESULTS OF ILC DATA DEVICE CORP. POWER CONTROLLER #3

POWER CONTROLLER RATED AT 15 AMPS

SSPC #3 = 19645 SSP 21116-015 9046 (S/N 005)

POST HARNESS NUMBER CHECKOUT	TURN-ON TIME (100% LOAD) MIL-P-81653C	TURN-OFF TIME (100% LOAD) MIL-P-81653C	VOLTAGE DROP (100% LOAD) MIL-P-81653C	TRIP TIME (300% LOAD) MIL-P-81653C	TRIP TIME CURRENT DURATION (300% LOAD)
INIT. CHECKOUT	776 μs	724 μs	0.8080 V	[1]	236.00 ms
FILOTEX #237	772 μs	736 μs	0.7120 V	[1]	248.80 ms
TENSOLITE #242	776 μs	720 μs	0.7200 V	[1]	247.20 ms
THERMATICS #247	776 μs	736 μs	0.6980 V	[1]	249.60 ms
NEMA 3 #257	776 μs	712 μs	0.7050 V	[1]	248.96 ms
M22759 #207	784 μs	712 μs	0.7110 V	[1]	248.96 ms
M81381 #202	[2]	[2]	[2]	[2]	[2]

[1] - TRIP TIME DATA NOT ACQUIRED BECAUSE THE STATUS AND TRIP SIGNALS WERE NOT FUNCTIONING PROPERLY.

[2] - DATA WAS NOT OBTAINED BECAUSE THE POWER CONTROLLER DID NOT FUNCTION PROPERLY FOLLOWING THE DRY ARC PROPAGATION TEST ON M81381.

TABLE 110 - FUNCTIONAL TEST RESULTS OF KILOVAC POWER CONTROLLER #1

POWER CONTROLLER RATED AT 15 AMPS

PC #1 = FSCM 18741 EPC-3 (9029 X001)

POST HARNESS NUMBER CHECKOUT	CONTACT BOUNCE (MAKE) (100% LOAD) MIL-R-6106J	OPERATE TIME (100% LOAD) MIL-R-6106J	CONTACT BOUNCE (BREAK) (100% LOAD) MIL-R-6106J	RELEASE TIME (100% LOAD) MIL-R-6106J	VOLTAGE DROP (100% LOAD) MIL-R-6106J	TRIP TIME (300% LOAD) MIL-R-6106J	TRIP TIME CURRENT DURATION (300% LOAD)
INIT. CHECKOUT	694 μs	11.488 ms	NO BOUNCE	4.816 ms	0.0621 V	11.942 s	11.865 s
FILOTEX #237	636 μs	10.592 ms	NO BOUNCE	4.544 ms	0.0644 V	12.249 s	12.172 s
TENSOLITE #242	650 μs	9.600 ms	NO BOUNCE	5.296 ms	0.0605 V	12.057 s	11.942 s
THERMATICS #247	650 μs	9.504 ms	NO BOUNCE	5.312 ms	0.0614 V	12.134 s	12.096 s
NEMA 3 #257	660 μs	11.200 ms	NO BOUNCE	4.336 ms	0.0607 V	11.865 s	11.788 s
M22759 #207	NO BOUNCE	11.040 ms	NO BOUNCE	5.560 ms	0.0609 V	12.019 s	12.057 s
M81381 #202	655 μs	11.400 ms	NO BOUNCE	5.080 ms	0.0646 V	12.864 s	12.864 s

TABLE III - FUNCTIONAL TEST RESULTS OF KILOVAC POWER CONTROLLER #2

POWER CONTROLLER RATED AT 15 AMPS

PC #2 - FSCM 18741 EPC-3 (9029 X002)

POST HARNESS NUMBER CHECKOUT	CONTACT BOUNCE (MAKE) (100% LOAD) MIL-R-6106J	OPERATE TIME (100% LOAD) MIL-R-6106J	CONTACT BOUNCE (BREAK) (100% LOAD) MIL-R-6106J	RELEASE TIME (100% LOAD) MIL-R-6106J	VOLTAGE DROP (100% LOAD) MIL-R-6106J	TRIP TIME (300% LOAD) MIL-R-6106J	TRIP TIME CURRENT DURATION (300% LOAD)
INIT. CHECKOUT	542 μs	11.104 ms	NO BOUNCE	4.688 ms	0.0619 V	11.491 s	11.433 s
FILOTEX #237	538 μs	9.376 ms	NO BOUNCE	5.280 ms	0.0621 V	12.959 s	12.518 s
TENSOLITE #242	964 μs	9.440 ms	NO BOUNCE	4.848 ms	0.0651 V	12.748 s	12.710 s
THERMATICS #247	596 μs	9.600 ms	NO BOUNCE	5.552 ms	0.0627 V	12.595 s	12.518 s
NEMA 3 #257	602 μs	10.944 ms	NO BOUNCE	4.592 ms	0.0638 V	12.249 s	12.211 s
M22759 #207	NO BOUNCE	10.800 ms	NO BOUNCE	4.700 ms	0.0643 V	12.339 s	12.228 s
M81381 #202	NO BOUNCE	10.040 ms	NO BOUNCE	3.960 ms	0.0700 V	13.401 s	13.363 s

TABLE 112 - FUNCTIONAL TEST RESULTS OF KILOVAC POWER CONTROLLER #3

POWER CONTROLLER RATED AT 15 AMPS

PC #3 - FSCM 18741 EPC-3 (9029 X003)

POST HARNESS NUMBER CHECKOUT	CONTACT BOUNCE (MAKE) (100% LOAD) MIL-R-6106J	OPERATE TIME (100% LOAD) MIL-R-6106J	CONTACT BOUNCE (BREAK) (100% LOAD) MIL-R-6106J	RELEASE TIME (100% LOAD) MIL-R-6106J	VOLTAGE DROP (100% LOAD) MIL-R-6106J	TRIP TIME (300% LOAD) MIL-R-6106J	TRIP TIME CURRENT DURATION (300% LOAD)
INIT. CHECKOUT	674 µs	10.400 ms	NO BOUNCE	3.680 ms	0.0667 V	12.211 s	12.172 s
FILOTEX #237	614 µs	9.024 ms	NO BOUNCE	4.192 ms	0.0654 V	12.172 s	12.096 s
TENSOLITE #242	702 µs	8.960 ms	NO BOUNCE	4.400 ms	0.0664 V	12.326 s	12.288 s
THERMATICS #247	1200 µs	12.320 ms	NO BOUNCE	3.344 ms	0.0687 V	11.904 s	11.827 s
NEMA 3 #257	640 µs	10.336 ms	NO BOUNCE	4.144 ms	0.0660 V	11.904 s	11.865 s
M22759 #207	NO BOUNCE	10.400 ms	NO BOUNCE	3.810 ms	0.0760 V	12.096 s	12.019 s
M81381 #202	NO BOUNCE	10.040 ms	NO BOUNCE	3.960 ms	0.0724 V	12.979 s	12.940 s

TABLE 113 - FUNCTIONAL TEST RESULTS OF EATON POWER CONTROLLER #1

POWER CONTROLLER RATED AT 40 AMPS

PC #1 - 81640 SM-VAR 40/150 X-80293 9032

POST HARNESS NUMBER CHECKOUT	CONTACT BOUNCE (MAKE) (100% LOAD) MIL-R-6106J	OPERATE TIME (100% LOAD) MIL-R-6106J	CONTACT BOUNCE (BREAK) (100% LOAD) MIL-R-6106J	RELEASE TIME (100% LOAD) MIL-R-6106J	VOLTAGE DROP (100% LOAD) MIL-R-6106J	TRIP TIME (300% LOAD) MIL-R-6106J	TRIP TIME CURRENT DURATION (300% LOAD)
INIT. CHECKOUT	NO BOUNCE	16.448 ms	NO BOUNCE	14.400 ms	0.0150 V	76.320 ms	83.520 ms
FILOTEX #236	NO BOUNCE	15.872 ms	NO BOUNCE	15.616 ms	0.0217 V	76.000 ms	82.560 ms
TENSOLITE #241	NO BOUNCE	16.960 ms	NO BOUNCE	15.936 ms	0.0098 V	76.320 ms	82.240 ms
THERMATICS #246	NO BOUNCE	16.704 ms	NO BOUNCE	15.360 ms	0.0130 V	76.160 ms	81.920 ms
NEMA 3 #256	NO BOUNCE	16.256 ms	NO BOUNCE	14.784 ms	0.0126 V	76.000 ms	81.920 ms
M22759 #206	NO BOUNCE	17.240 ms	NO BOUNCE	16.720 ms	0.0114 V	74.880 ms	81.600 ms
M81381 #201	NO BOUNCE	18.160 ms	NO BOUNCE	16.200 ms	0.0114 V	75.200 ms	81.600 ms

TABLE I14 - FUNCTIONAL TEST RESULTS OF EATON POWER CONTROLLER #2

POWER CONTROLLER RATED AT 40 AMPS

PC #2 - 81640 SM-VAR 40/150 X-80293 9032

POST HARNESS NUMBER CHECKOUT	CONTACT BOUNCE (MAKE) (100% LOAD) MIL-R-6106J	OPERATE TIME (100% LOAD) MIL-R-6106J	CONTACT BOUNCE (BREAK) (100% LOAD) MIL-R-6106J	RELEASE TIME (100% LOAD) MIL-R-6106J	VOLTAGE DROP (100% LOAD) MIL-R-6106J	TRIP TIME (300% LOAD) MIL-R-6106J	TRIP TIME CURRENT DURATION (300% LOAD)
INIT. CHECKOUT	NO BOUNCE	18.368 ms	NO BOUNCE	17.024 ms	0.0168 V	64.480 ms	71.200 ms
FILOTEX #236	2.16 ms	18.432 ms	NO BOUNCE	15.552 ms	0.0210 V	64.640 ms	72.000 ms
TENSOLITE #241	NO BOUNCE	19.960 ms	NO BOUNCE	16.832 ms	0.0216 V	64.640 ms	70.560 ms
THERMATICS #246	NO BOUNCE	17.360 ms	NO BOUNCE	17.040 ms	0.0213 V	64.480 ms	70.240 ms
NEMA 3 #256	NO BOUNCE	17.536 ms	NO BOUNCE	15.040 ms	0.0208 V	64.480 ms	72.320 ms
M22759 #206	NO BOUNCE	17.760 ms	NO BOUNCE	16.680 ms	0.0315 V	64.800 ms	71.360 ms
M81381 #201	945 μs	17.920 ms	NO BOUNCE	16.480 ms	0.0256 V	64.320 ms	70.400 ms

TABLE 115 - FUNCTIONAL TEST RESULTS OF EATON POWER CONTROLLER #3

POWER CONTROLLER RATED AT 40 AMPS

PC #3 - 81640 SM-VAR 40/150 X-80293 9032

POST HARNESS NUMBER CHECKOUT	CONTACT BOUNCE (MAKE) (100% LOAD) MIL-R-6106J	OPERATE TIME (100% LOAD) MIL-R-6106J	CONTACT BOUNCE (BREAK) (100% LOAD) MIL-R-6106J	RELEASE TIME (100% LOAD) MIL-R-6106J	VOLTAGE DROP (100% LOAD) MIL-R-6106J	TRIP TIME (300% LOAD) MIL-R-6106J	TRIP TIME CURRENT DURATION (300% LOAD)
INIT. CHECKOUT	NO BOUNCE	17.920 ms	NO BOUNCE	16.704 ms	0.0140 V	66.080 ms	73.120 ms
FILOTEX #236	NO BOUNCE	17.664 ms	NO BOUNCE	15.616 ms	0.0162 V	65.760 ms	72.800 ms
TENSOLITE #241	NO BOUNCE	16.704 ms	NO BOUNCE	14.528 ms	0.0135 V	65.600 ms	73.600 ms
THERMATICS #246	NO BOUNCE	16.896 ms	NO BOUNCE	14.720 ms	0.0170 V	65.600 ms	72.000 ms
NEMA 3 #256	NO BOUNCE	16.576 ms	NO BOUNCE	14.400 ms	0.0173 V	65.600 ms	72.320 ms
M22759 #206	NO BOUNCE	17.680 ms	NO BOUNCE	16.040 ms	0.0140 V	65.280 ms	72.320 ms
M81381 #201	NO BOUNCE	16.200 ms	NO BOUNCE	15.360 ms	0.0196 V	65.120 ms	72.640 ms

TABLE 116 - FUNCTIONAL TEST RESULTS OF HARTMAN POWER CONTROLLER #1

POWER CONTROLLER RATED AT 40 AMPS

PC #1 - AHEV-775-1 (ENG. PROT. #1)

POST HARNESS NUMBER CHECKOUT	CONTACT BOUNCE (MAKE) (100% LOAD) MIL-R-6106J	OPERATE TIME (100% LOAD) MIL-R-6106J	CONTACT BOUNCE (BREAK) (100% LOAD) MIL-R-6106J	RELEASE TIME (100% LOAD) MIL-R-6106J	VOLTAGE DROP (100% LOAD) MIL-R-6106J	TRIP TIME (300% LOAD) MIL-R-6106J	TRIP TIME CURRENT DURATION (300% LOAD)
INIT. CHECKOUT	NO BOUNCE	53.376 ms	NO BOUNCE	17.088 ms	0.0349 V	20.800 ms	52.000 ms
FILOTEX #236	NO BOUNCE	52.992 ms	NO BOUNCE	16.704 ms	0.0490 V	20.416 ms	51.840 ms
TENSOLITE #241	NO BOUNCE	52.922 ms	NO BOUNCE	15.424 ms	0.0357 V	20.992 ms	52.992 ms
THERMATICS #246	NO BOUNCE	53.504 ms	NO BOUNCE	16.576 ms	0.0386 V	20.736 ms	51.840 ms
NEMA 3 #256	NO BOUNCE	53.376 ms	NO BOUNCE	14.400 ms	0.0282 V	20.480 ms	51.200 ms
M22759 #206	NO BOUNCE	53.504 ms	NO BOUNCE	15.100 ms	0.0492 V	20.480 ms	51.200 ms
M81381 #201	NO BOUNCE	53.440 ms	NO BOUNCE	17.040 ms	0.0363 V	20.240 ms	49.760 ms

TABLE 117 - FUNCTIONAL TEST RESULTS OF HARTMAN POWER CONTROLLER #2

POWER CONTROLLER RATED AT 40 AMPS

PC #2 - AHEV-775-1 (ENG. PROT. #2)

POST HARNESS NUMBER CHECKOUT	CONTACT BOUNCE (MAKE) (100% LOAD) MIL-R-6106J	OPERATE TIME (100% LOAD) MIL-R-6106J	CONTACT BOUNCE (BREAK) (100% LOAD) MIL-R-6106J	RELEASE TIME (100% LOAD) MIL-R-6106J	VOLTAGE DROP (100% LOAD) M.L-R-6106J	TRIP TIME (300% LOAD) MIL-R-6106J	TRIP TIME CURRENT DURATION (300% LOAD)
INIT. CHECKOUT	NO BOUNCE	53.632 ms	NO BOUNCE	19.008 ms	0.0389 V	22.320 ms	45.280 ms
FILOTEX #236	NO BOUNCE	65.280 ms	NO BOUNCE	16.000 ms	0.0341 V	22.400 ms	46.080 ms
TENSOLITE #241	NO BOUNCE	53.376 ms	NO BOUNCE	16.512 ms	0.0311 V	22.400 ms	53.504 ms
THERMATICS #246	NO BOUNCE	65.280 ms	NO BOUNCE	16.512 ms	0.0428 V	22.400 ms	45.312 ms
NEMA 3 #256	NO BOUNCE	53.248 ms	NO BOUNCE	15.424 ms	0.0315 V	22.400 ms	45.600 ms
M22759 #206	NO BOUNCE	53.500 ms	NO BOUNCE	14.850 ms	0.0364 V	22.480 ms	45.760 ms
M81381 #201	NO BOUNCE	53.440 ms	NO BOUNCE	16.760 ms	0.0427 V	22.400 ms	45.920 ms

TABLE 118 - FUNCTIONAL TEST RESULTS . [illegible]TMAN POWER CONTROLLER #3

POWER CONTROLLER RATED AT 40 AMPS

PC #3 = AHEV-775-1 (ENG. PROT. #3)

POST HARNESS NUMBER CHECKOUT	CONTACT BOUNCE (MAKE) (100% LOAD) MIL-R-6106J	OPERATE TIME (100% LOAD) MIL-R-6106J	CONTACT BOUNCE (BREAK) (100% LOAD) MIL-R-6106J	RELEASE TIME (100% LOAD) MIL-R-6106J	VOLTAGE DROP (100% LOAD) MIL-R-6106J	TRIP TIME (300% LOAD) MIL-R-6106J	TRIP TIME CURRENT DURATION (300% LOAD)
INIT. CHECKOUT	NO BOUNCE	53.760 ms	NO BOUNCE	24.512 ms	0.0556 V	22.720 ms	44.640 ms
FILOTEX #236	NO BOUNCE	65.024 ms	NO BOUNCE	16.448 ms	0.0425 V	22.848 ms	53.376 ms
TENSOLITE #241	NO BOUNCE	52.864 ms	NO BOUNCE	14.656 ms	0.0325 V	22.912 ms	43.776 ms
THERMATICS #246	NO BOUNCE	64.768 ms	NO BOUNCE	14.848 ms	0.0330 V	22.912 ms	43.648 ms
NEMA 3 #256	NO BOUNCE	52.736 ms	NO BOUNCE	13.632 ms	0.0310 V	22.800 ms	42.880 ms
M22759 #206	NO BOUNCE	53.120 ms	NO BOUNCE	13.504 ms	0.0420 V	22.720 ms	42.400 ms
M81381 #201	NO BOUNCE	52.640 ms	NO BOUNCE	16.600 ms	0.0354 V	22.800 ms	45.532 ms

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